STOPPING
WATER POLLUTION
AT ITS SOURCE

MISA
Municipal/Industrial Strategy for Abatement

FLUCTUATIONS OF TRACE CONTAMINANTS IN MUNICIPAL SEWAGE TREATMENT PLANTS

PHASE II FIELD STUDIES

Environment
Ontario

ISBN 0-7729-5846-7

FLUCTUATIONS OF TRACE CONTAMINANTS IN MUNICIPAL SEWAGE TREATMENT PLANTS

PHASE II FIELD STUDIES

Report prepared by:
Canviro Consultants
A Division of CH2M HILL Limited

AUGUST 1991

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PIBS 1170
log 89-2307-015

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ACKNOWLEDGEMENTS

This study was funded by Environment Canada, the Ontario Ministry of the Environment, the Great Lakes Water Quality Toxics Subcommittee, and the Department of Supply and Services.

Dr. Henryk Melcer of Environment Canada's Wastewater Technology Centre in Burlington, Ontario served as Project Scientific Liaison Officer.

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1.0 INTRODUCTION

Over the past decade, national attention has been drawn to the issue of trace contaminants in the environment and the need to control the discharge of these toxic compounds in treated effluents from municipal sewage treatment plants (STPs). Research(1,2,3) has shown that the biological processes in municipal STPs are capable of achieving a high degree of trace contaminant removal when operated under stable conditions and after acclimation of the microbial species to the contaminants present in the wastewater. In full-scale systems, steady state conditions seldom exist. Under such circumstances, the biological processes are exposed to highly variable input loads of a wide range of trace contaminants. The degree of variability which can be tolerated by conventional biological processes and the dynamic response of these processes to transient conditions is poorly understood.

An improved understanding of the response characteristics of conventional treatment facilities to typical input fluctuations in trace contaminants would assist regulatory authorities in the development of appropriate sewer use management strategies. Accordingly, CANVIRO CONSULTANTS has undertaken an investigation aimed at defining the dynamic behaviour characteristics of full-scale STPs. The investigation has been undertaken in three phases. In Phase I, a comprehensive technical review was completed with the objective of compiling and collating the information presently available with respect to the fate of trace contaminants in municipal STPs(4). Phase II of the program involved an intensive sampling program at three full-scale Ontario STPs to quantify the degree of variability in the concentration of trace contaminants in the influent and effluent streams from such facilities. In Phase III, laboratory-scale activated sludge treatment units were operated under dynamic loading conditions to verify the Phase II findings under controlled conditions.

1.1 Summary of Phase I Investigations

The technical review(4), completed in 1987, focused on characterizing trace contaminant concentrations in municipal STP influents, effluents, sludges and internal recycle streams. Particular attention was paid to data identifying the dynamic fluctuation patterns on the variability of these trace contaminants. Contaminant removal efficiencies were summarized and the mechanisms responsible for removal were identified. Mathematical models describing the removal mechanisms were also assessed.

The technical review verified that little information was available with respect to the variability of trace contaminant concentrations at full-scale STPs. Most characterization studies undertaken to-date have been based on composite sampling approaches which mask the time-dependent variations in concentration. Where data were available, they typically dealt with heavy metal concentrations and rarely with trace organics. There were often inconsistencies between studies with respect to sampling frequency, sampling method and sample location which make it extremely difficult to interpret the results. Some studies reported that influent and effluent concentrations of some contaminants were highly correlated and data suggested that concentrations in treated effluents were as variable as those in the raw wastewater. However, the database was extremely limited and no investigation of the dynamic response characteristics of full-scale STPs to variable influent trace contaminant concentrations was identified during the technical review.

1.2 Scope of Phase II

The primary objectives of the Phase II investigations were to quantify the degree of variability of selected trace contaminants experienced at typical full-scale STPs in Ontario and to determine the extent of the effluent response to the dynamic fluctuations in influent strength. In addition, an effort was made to generate dynamic models that would describe the non-steady state behaviour of these facilities.

Three full-scale STPs were selected for intensive monitoring; the Waterloo STP in Waterloo, Ontario; the Galt STP in Cambridge, Ontario and the Welland STP in Welland, Ontario.

It was intended that this selection would cover a range of influent quality from primarily domestic (Waterloo STP) through light industrial (Galt STP) to heavy industrial (Welland STP). The raw influent wastewater and the secondary effluent, prior to disinfection, were sampled at each facility at 2 hour intervals for 8 days. Details regarding the sampling program are presented in Section 2.0 of the report.

A short-list of target trace contaminants was developed based on those that had been most frequently identified in earlier investigations(5,6,7). The short list included six commonly found heavy metals, polyaromatic hydrocarbons (PAHs), phenolic compounds, and volatile chlorinated and non-chlorinated organic compounds. All influent and effluent samples were analyzed for these target trace contaminants, as well as conventional contaminants. Details regarding the analytical protocols are presented in Section 2.0. Additional sampling and analysis were also undertaken during the monitoring period at each plant to establish system operating conditions. At the same time, the acute and chronic toxicity of the raw influents, secondary effluents and chlorinated final effluents at each facility were measured.

1.3 Report Format

This report presents the results of the sampling programs undertaken at the three full-scale STPs. Details regarding the sampling program and analytical procedures are presented in Section 2.0, along with detailed descriptions of the three treatment facilities involved in the field studies. Results for each individual full-scale STP are reported in separate chapters - Waterloo STP in Section 3.0, Welland STP in Section 4.0 and Galt STP in Section 5.0. Section 6.0 describes the development of dynamic models characterizing the response of the three sampled STPs for selected trace contaminants. Section 7.0 provides a summary of the field study results, along with a discussion of the implications of the data from a trace contaminant management standpoint. Supporting information is presented in the report appendices.

2.0 EXPERIMENTAL PROCEDURES

2.1 Descriptions of STPs

2.1.1 Waterloo STP

2.1.1.1 Design Data

The Waterloo STP is a conventional activated sludge facility designed to treat an average daily flow of 45,460 m^3/d with a peak flow capacity of 113,650 m^3/d. The plant was designed to accommodate an influent strength of 270 mg/L BOD_5 and 270 mg/L TSS. A schematic flowsheet of the facility is given in Figure 1. The plant includes two parallel, independent sections which share a common influent works (screening and lift station) and a common outfall. The old section of the plant (Stage 1) provides a rated capacity of 27,276 m^3/d (peak capacity 45,460 m^3/d) while the newer Stage II Phase I section provides a rated capacity of 18,184 m^3/d (peak capacity 68,190 m^3/d). Each section has a dedicated headworks, including flow measurement and grit removal, primary clarification, aeration, secondary clarification and two-stage anaerobic sludge digestion. There is no intermixing of liquid streams or sludges prior to discharge. Ferrous chloride is metered separately to the aeration sections of each facility for phosphorus removal. Design criteria for the key unit processes are summarized in Table 1.

Other than the sizes of the individual tanks in the Stage I and Stage II - Phase 1 plants, the major difference between the plants relates to the method of oxygen transfer to the aeration basins. Stage I utilizes submerged turbines, with three 22.4 kW turbine mixers in each of four single-pass aeration tanks and two 149 kW blowers providing the air supply through 66 spargers in each tank. The Stage II - Phase 1 plant utilizes four 22.4 kW surface aerators in each of two four-celled aeration tanks.

The secondary effluent is disinfected prior to discharge to the Grand River by chlorination. Chlorine is fed from tonne cylinders to the secondary effluent from the Stage 1 plant, which then combines with the secondary effluent from the

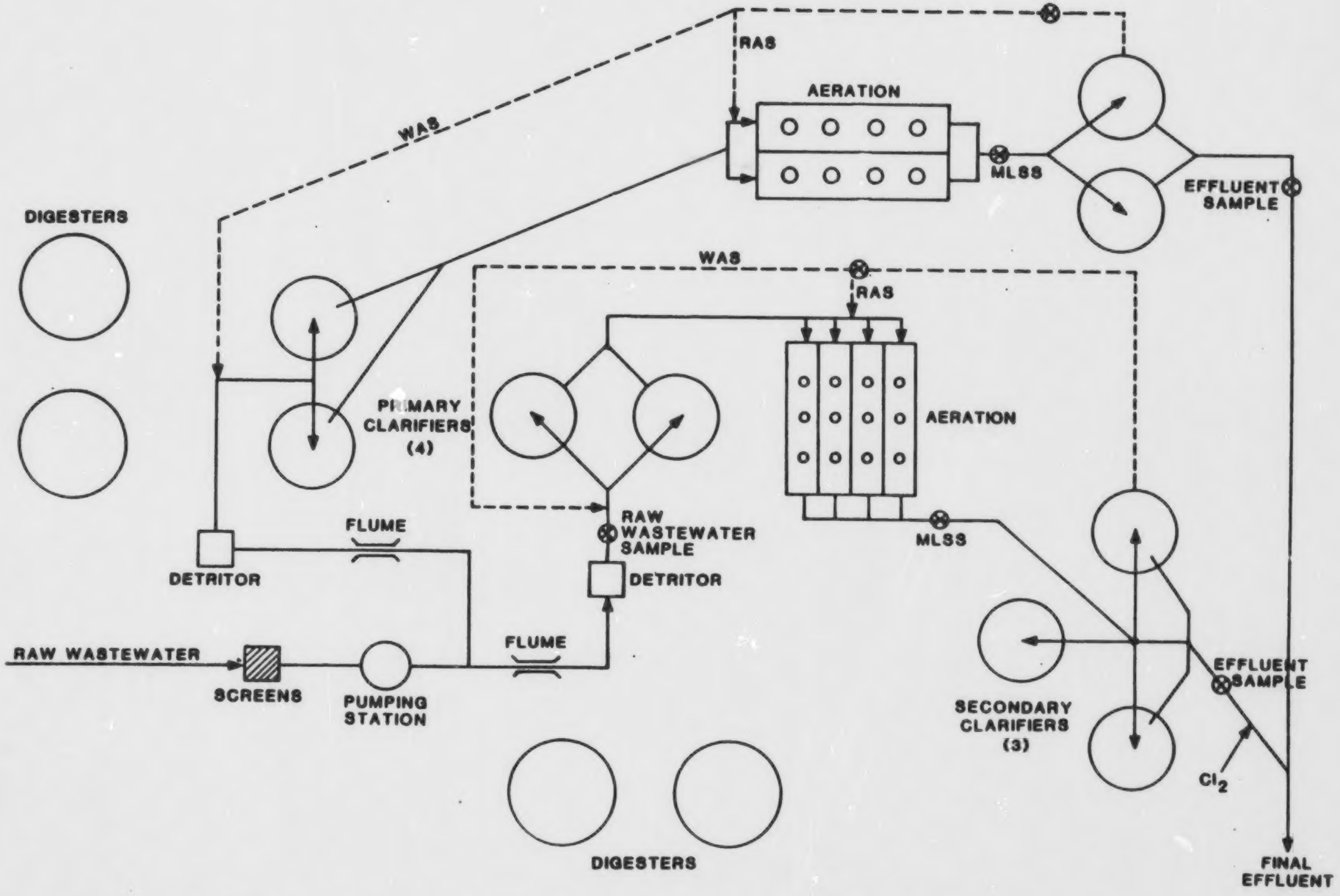
RAS
AERATION
WAS
MLSS
EFFLUENT SAMPLE
DIGESTERS
WAS
RAS
PRIMARY CLARIFIERS (4)
AERATION
RAW WASTEWATER SAMPLE
FLUME
DETRITOR
MLSS
DETRITOR
FLUME
RAW WASTEWATER
SCREENS
PUMPING STATION
SECONDARY CLARIFIERS (3)
EFFLUENT SAMPLE
Cl_2
DIGESTERS
FINAL EFFLUENT

FIGURE 1: PROCESS FLOW SCHEMATIC OF WATERLOO STP

Table 1
DESIGN SUMMARY FOR WATERLOO STP

	Stage I	Stage II - Phase 1
Grit Removal	2 Detritors 4.3 m x 4.3 m x 0.49 m HRT = 0.94 min	1 Detritor 7.9m x 7.9 m x 0.70 m HRT = 0.95 min (Peak)
Primary Clarifiers	2 @ 22.9 m x 4.0 m Load = 33.3 m³/m².d HRT = 3.1 h	2 @ 22.9 m x 3.05 m Load = 22.2 m³/m².d HRT = 3.6 h
Aeration	4 tanks @ 40.8 m x 9.9 m x 4.7 m Single pass, submerged turbine HRT = 6.7 h	2 tanks @ 47.7 m x 11.6 m x 5.3 m Mechanical aeration HRT = 7.8 h
Secondary Clarifiers	2 @ 19.8 m x 3.05 m 1 @ 27.4 m x 3.05 m Load = 22.8 m³/m².d HRT = 3.4 h	2 @ 36.5 m x 3.05 m Load = 8.7 m³/m².d HRT = 8.5 h

(KIR21/272W)

Stage II - Phase I plant. The 1120 m outfall to the Grand River provides adequate contact time for disinfection prior to discharge.

2.1.1.2 Historical Performance and Operating Characteristics

The Waterloo STP has consistently produced a high quality effluent although operating at near design capacity. Annual average influent and effluent quality data are summarized for the years 1981 to 1986 in Table 2. Average daily flow for the one-year period September 1985 to September 1986 which encompasses the sampling period was 44,680 m^3/d (98 percent of design capacity). The plant is operated so that approximately 60 percent of the raw sewage flow is directed to Stage I and the remaining 40 percent is directed to Stage II.

Despite operating at near design capacity, historical data for the 1985/1986 periods show that the Waterloo STP achieved partial nitrification. Influent TKN averaged 30.4 mg/L during this period while the effluent NH_3-N averaged 5.5 mg/L. No historic nitrate or nitrite data are available.

Key operational parameters for the biological systems (Stage I and Stage II - Phase 1) for the Sept. 1985 to Sept. 1986 period are summarized in Table 3. The relatively high SRT (7 to 9 days) estimated for the plant supports the conclusion regarding partial nitrification based on historic data.

2.1.1.3 Industrial Wastewater Contributions

Raw sewage at the Waterloo STP would be considered to be primarily domestic in nature. Annual sanitary sewer discharges to the facility from industrial and institutional contributors are summarized in Table 4. On a daily basis, these contributors total approximately 6870 m^3/d or about 15.4 percent of the plant influent flow. This total includes about 2310 m^3/d of flow from the two local universities which is primarily domestic waste. A local brewery and a distillery contribute 37 percent of the total industrial flow to the Waterloo STP.

Table 2
INFLUENT AND EFFLUENT QUALITY DATA - WATERLOO STP

	Influent			Effluent		
	BOD_5	TSS	TP	BOD_5	TSS	TP
1981	211	230	6.51	9.3	7.5	0.73
1982	389	786	9.52	11.0	10.9	0.79
1983	273	485	8.23	14.2	9.0	0.78
1984	260	433	6.56	12.8	10.4	0.98
1985	218	402	6.46	6.8	8.9	0.75
1986	203	405	6.50	6.8	9.3	0.90

Table 3
BIOLOGICAL SYSTEM OPERATING CONDITIONS - WATERLOO STP

	Stage I	Stage II - Phase 1
HRT (h)	7.8	7.4
BOD_5 Load (kg/d)	2832	1881
Volumetric Load (kg/m³.d)	0.37	0.31
MLSS	2220	2390
MLVSS %	68.1	80.3
F/M (kg/kg VSS.d)	0.25	0.17
SRT (d)*	8.5	7.2
DO (mg/L)	2.9	2.9
SVI	212	268

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* Based on estimated WAS flow.

Table 4
INSTITUTIONAL/INDUSTRIAL CONTRIBUTORS TO WATERLOO STP

Company	SIC	Annual Sanitary Sewer Discharge (m^3)
Wilfrid Laurier Univ.	-	61,639
Seagrams Distillers	2085	311,403
Sunar Industries	2542, 2552, 2521	41,644
Waterloo Spring Co. Ltd.	3429, 3495	5,993
Bauer Industries	2291, 2297	7,113
Graphico Space Circuits	3679	79,105
Work Wear	-	36,807
La-Z-Boy Canada	2512	26,368
Brick Breweries	2082	9,593
Canbar Products	2449, 2499, 3079	2,506
Swan Dust Control	-	12,129
Northfield Metal Prodcuts	3429, 3499, 3443	107,870
Labatts Brewery	2082	615,027
University of Waterloo	-	781,359
Kraus Carpet Mills	2272	55,378
Chrome Print	2272	151,359
Electro Porcelain Co. Ltd.	3264, 3643	25,562
Pillers Sausages	2013	59,020
Strudex Fibres	2824	61,230
Designer Classic Carpet	2271	19,976
Meat Connection	2011	13,575
Raytheon Canada	3662	12,944
Heidt Metal Products	2531, 2542, 2514	3,457
H & O Centreless Grinding	3451, 3452, 3599	2,677
Custom Trim Ltd.	3714	2,443
Geo Cluthe Mfg.	3079	1,017
Total		2,507,192

(KIR21/272W)

Digested sludges from the Waterloo STP are applied to agricultural land and, as shown in Table 5, contain relatively low metal concentrations compared to their nitrogen content. These data tend to confirm the small industrial contribution of wastewater to the Waterloo STP.

2.1.2 Welland STP

2.1.2.1 Design Data

The Welland STP is a conventional activated sludge facility designed to treat an average daily flow of 45,460 m^3/d. A schematic flowsheet for the facility is given in Figure 2. As the collection system in the City of Welland contains a significant component of combined sewers, excessive hydraulic loading is controlled by storage of raw sewage in the trunk sewer feeding the plant. In addition, approximately 46,000 m^3 of offline storage capacity is provided in one of the collectors tributary to the trunk sewer.

Plant headworks include manually and automatically cleaned bar screens and a detritor. Pre-aeration is provided upstream of four parallel primary clarifiers which feed eight square aeration tanks each equipped with a 45 kW mechanical surface aerator. The aeration tanks are configured to allow a wide range of parallel and series flow configurations. Mixed liquor from the aeration tanks is split to six rectangular clarifiers and two parallel square clarifiers. Each set of secondary clarifiers is served by a dedicated chlorine contactor for final effluent disinfection. Waste activated sludge is co-thickened in the primary clarifiers and excess sludge undergoes two stage anaerobic digestion prior to land application. Supernatant from the secondary digester returns to the plant in the trunk sewer upstream of the wet well. Ferrous chloride is added to the aeration tank influent for phosphorus removal. Key design data for major unit processes are summarized in Table 6.

2.1.2.2 Historical Performance and Operating Characteristics

The Welland STP has historically complied with its effluent guidelines of 25 mg/L BOD_5, 25 mg/L TSS and 1.0 mg/L TP while operating at about 85 percent of design hydraulic

Table 5
AMMONIUM PLUS NITRATE NITROGEN TO METAL RATIOS FOR WATERLOO STP SLUDGES

Parameter	Ontario Guideline Limit for Metal Ratios	Waterloo	
		Mean	Std. Dev.
Chromium	6	46	13
Zinc	4	25	3
Copper	10	17	10
Nickel	40	379	146
Lead	15	94	33
Cadmium	500	8210	4628
Cobalt	50	3050	1758
Mercury	1500	7362	1543
Molybdenum	180	3535	1056
Arsenic	100	2720	648
Selenium	500	6305	1930

Notes: 1) All values are based on 1985 sludge data.
2) Values less than the Guidelines Limits are out-of-compliance.

(KIR21/272W)

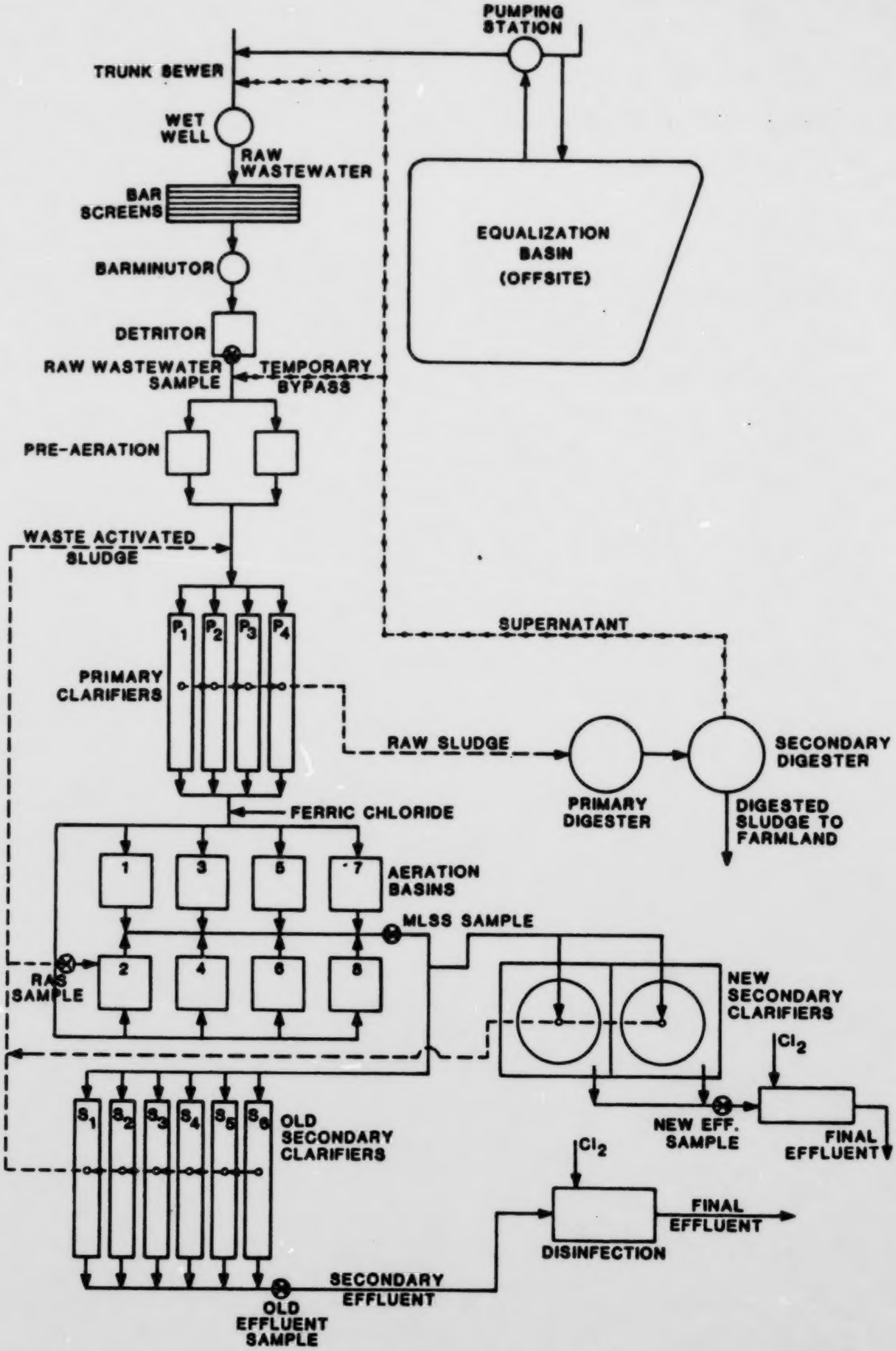
PUMPING STATION
TRUNK SEWER
WET WELL
RAW WASTEWATER
BAR SCREENS
BARMINUTOR
DETRITOR
EQUALIZATION BASIN (OFFSITE)
RAW WASTEWATER SAMPLE
TEMPORARY BYPASS
PRE-AERATION
WASTE ACTIVATED SLUDGE
P_1
P_2
P_3
P_4
PRIMARY CLARIFIERS
SUPERNATANT
RAW SLUDGE
PRIMARY DIGESTER
SECONDARY DIGESTER
DIGESTED SLUDGE TO FARMLAND
FERRIC CHLORIDE
1
3
5
7
AERATION BASINS
MLSS SAMPLE
2
4
6
8
RAS SAMPLE
NEW SECONDARY CLARIFIERS
Cl_2
NEW EFF. SAMPLE
FINAL EFFLUENT
S_1
S_2
S_3
S_4
S_5
S_6
OLD SECONDARY CLARIFIERS
Cl_2
DISINFECTION
FINAL EFFLUENT
SECONDARY EFFLUENT
OLD EFFLUENT SAMPLE

FIGURE 2: PROCESS FLOW SCHEMATIC OF WELLAND STP

Table 6
DESIGN SUMMARY FOR WELLAND STP

Grit Removal	Detritor 7.9 m x 7.9 m x 0.9 m Design HRT = 1.8 min.
Primary Clarifiers	Four @ 45.8 x 6.1 m x 2.7 m Total Surface Area = 1120 m^2 Design Load = 30.9 $m^3/m^2.d$ Design HRT = 2.1 h
Aeration	8 cells @ 15.3 m x 15.3 m x 4.6 m Total Volume = 8490 m^3 Design HRT = 4.5 h (8 basins)
Secondary Clarifiers	6 @ 42.7 m x 6.1 m x 3.9 m 2 @ 36.6 m x 36.6 m x 3.8 m Total Surface Area = 4250 m^2 Design Load = 10.7 $m^3/m^2.d$ Design HRT = 8.6 h
Chlorine Contact	Total Volume = 1250 m^3 Design HRT = 40 min.

capacity. Average influent and effluent quality data for the period 1981 to 1986 are summarized in Table 7. Average daily flow for 1986 was 37,959 m³/d, equivalent to about 83 percent of design. The plant has traditionally operated with up to half of the aeration capacity offline to reduce energy costs because excess biological capacity is available for the low strength wastewater. During 1986, only four tanks were in operation, configured as four tanks in series. Return sludge was directed to the first tank where it mixed with the incoming wastewater. The plant operated with approximately 65 percent of the flow directed to the older rectangular clarifiers and 35 percent of the flow directed to the new clarifiers.

Key operational parameters for the biological component of the plant for 1986 are summarized in Table 8.

2.1.2.3 Industrial Wastewater Contributions

The City of Welland is a centre of heavy industry in the Regional Municipality of Niagara with food, steel, textile, rubber and plastic, electrical appliance manufacturing, carbon and graphite electrode manufacturing, agricultural implement fabricators and steel fabricators included in the industrial profile. Available data on major industrial discharges are summarized in Table 9. On a daily basis, the industrial flow contribution to the Welland STP was estimated to be 9500 m³/d or approximately 25 percent of the 1986 average daily flow to the plant. Commercial discharges represented an additional 2850 m³/d or 7.5 percent of the flow. Major contributors include a specialty steel mill, metal fabricators and a carbon electrode manufacturer.

Digested sludges from the Welland STP are applied to agricultural land and, despite the high industrial flow contribution, do not have a problem with high metal concentrations.

Table 7
INFLUENT AND EFFLUENT QUALITY DATA - WELLAND STP

	Influent			Effluent		
	BOD_5	TSS	TP	BOD_5	TSS	TP
1981	80.6	132.6	6.30	7.9	10.2	0.71
1982	100.0	187.0	7.90	11.0	12.0	1.10
1983	95.2	328.5	10.50	11.1	10.3	0.55
1984	124.9	149.4	6.88	15.8	12.5	0.36
1985	92.8	115.4	4.24	10.1	11.0	0.75
1986	76.0	129.8	3.50	13.3	10.1	0.60

Table 8
BIOLOGICAL SYSTEM OPERATING CONDITIONS - WELLAND STP

	(1986)
HRT (h)*	2.7
BOD_5 Load (kg/d)	2100.
MLSS (mg/L)	2380.
F/M Ratio*	0.59
Organic Loading* (kg $BOD_5/m^3.d$)	0.50
SRT (d)**	2.3
SVI	122.

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* Based on four aeration tanks operating

** Estimate based on recycle rate and MLSS concentration

Table 9
MAJOR INDUSTRIAL CONTRIBUTORS TO THE WELLAND STP

Company	SIC	Est. Annual Sanitary Sewer Discharge (m^3)
Vineland Canning	2033	5,080
Sunnyside Dairy	2026	27,000
Diversitech	3069	618,700
Shaw Pipe	3069	13,000
Atlas Steel	3312	230,000
Haun Drop Forge	3462	18,000
Union Carbide	3699	750,000

2.1.3 Galt STP

2.1.3.1 Design Data

The Galt STP is a conventional activated sludge facility serving the City of Cambridge in the Regional Municipality of Waterloo. The plant was designed to handle an average daily flow of 38,640 m^3/d at influent concentrations of 250 mg/L BOD_5 and suspended solids. A schematic flowsheet of the plant is given in Figure 3.

Headworks at the plant consist of automatically cleaned bar screen, comminution and grit removal in parallel 5.5 m diameter detritors. Primary clarification is provided in four circular 18.3 m diameter clarifiers upstream of four, single-pass aeration tanks each equipped with five mechanical aerators on a line-drive 29.4 kW motor. Mixed liquor is separated from the liquid effluent in four circular 22.9 m secondary clarifiers. Effluent is disinfected in two chlorine contactors in series prior to discharge to the Grand River. Waste activated sludge is co-thickened and the combined sludges are anaerobically digested prior to land application. The supernatant return for the secondary digesters is piped to the influent trunk sewer upstream of the plant; however, no supernatant is returned to the plant except in emergency situations.

Phosphorus removal at the plant has traditionally been accomplished by ferric chloride addition to the aeration tank effluent. However, during this study, the plant was evaluating ferrous chloride addition as an alternate means of achieving phosphorus removal. Chemical dosage had not been optimized at the time of sampling.

Key design data for major unit processes are summarized in Table 10.

2.1.3.2 Historical Performance and Operating Characteristics

The Cambridge STP has consistently complied with its design guidelines of 25 mg/L BOD_5 and suspended solids and 1.0 mg/L TP, as indicated by the data summary in Table 11. Average

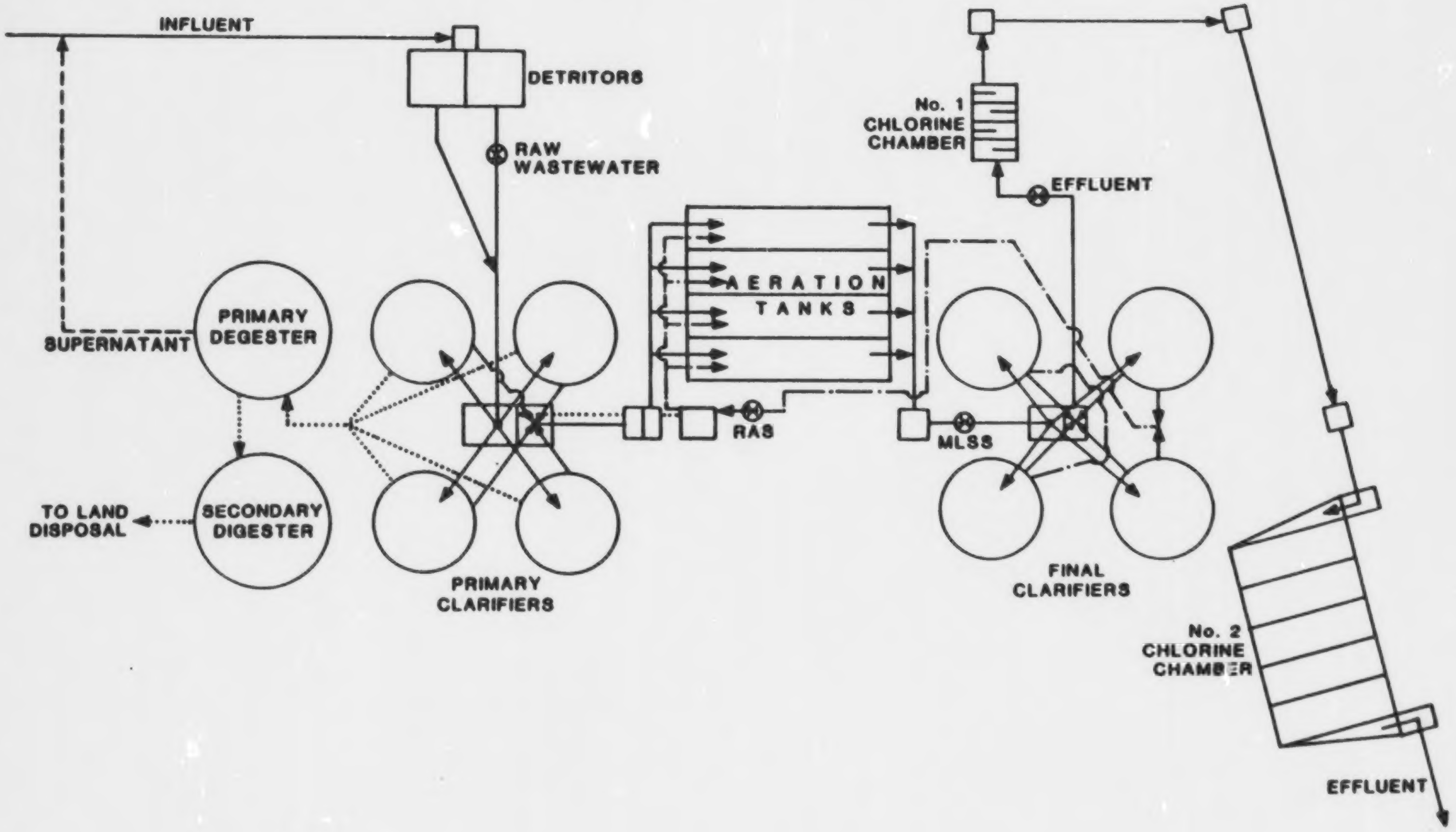
INFLUENT
DETRITORS
RAW WASTEWATER
No. 1 CHLORINE CHAMBER
EFFLUENT
AERATION TANKS
SUPERNATANT
PRIMARY DEGESTER
SECONDARY DIGESTER
TO LAND DISPOSAL
RAS
MLSS
PRIMARY CLARIFIERS
FINAL CLARIFIERS
No. 2 CHLORINE CHAMBER
EFFLUENT

FIGURE 3: PROCESS FLOW SCHEMATIC OF GALT STP

Table 10
DESIGN SUMMARY FOR GALT STP

Grit Removal	Two Detritors 5.5 m Diameter
Primary Clarifiers	Four @ 18.3 m Diameter, Two @ 2.7 m SWD Two @ 3.0 m SWD Total Surface Area = 1050 m^2 Design Load = 36.8 $m^3/m^2.d$ Design HRT = 1.5 h
Aeration	Four Single Pass Tanks @ 45.7 m x 9.1 m x 4.2 m Total Volume = 6600 m^3 Design HRT = 4.0 h
Secondary Clarifiers	Four @ 22.9 m x 3 m SWD Total Surface Area = 1650 m^2 Design Load = 23.4 $m^3/m^2.d$ Design HRT = 2.6 h
Chlorine Contact	Total Volume = 636 m^3 Design HRT = 41 min.

Table 11
INFLUENT AND EFFLUENT QUALITY DATA - GALT STP

	Influent			Effluent		
	BOD_5	TSS	TP	BOD_5	TSS	TP
1981	134.0	169.7	5.95	9.1	9.6	0.82
1982	143.5	173.2	5.84	9.3	10.4	0.76
1983	163.5	191.2	5.89	20.2	21.3	1.02
1984	142.7	168.6	5.91	14.1	14.1	0.89
1985	161.2	168.0	6.95	11.3	11.6	0.80
1986	172.3	184.1	5.60	15.3	18.7	0.80

Daily flow for the period September 1984 to September 1986, immediately prior to this sampling program, was 30,910 m^3/d, equivalent to 80 percent of design.

Historical plant data suggest that the plant achieves a high degree of nitrification in the summer months, reducing influent TKN levels of about 25 mg/L to effluent concentrations of about 5 mg/L. On an annual basis, the average effluent TKN concentration is about 14 mg/L suggesting approximately 40 percent nitrification. The system operates at an SRT of approximately 5 days which is consistent with the nitrification data reported. Other key operating parameters for the 1984 to 1986 period are summarized in Table 12.

Table 12
BIOLOGICAL SYSTEM OPERATING CONDITIONS - GALT STP

	(Sept/84 - Sept/86)
HRT (h)	5.1
MLSS (mg/L)	1300
MLVSS (mg/L)	1040
RSSS (mg/L)	2600
DO (mg/L)	3.2
SRT (d)	4.6
F/M	0.54
Organic Loading (kg BOD_5/m^3d)	0.56
Recycle Ratio	78%

2.1.3.3 Industrial Wastewater Contributions

The collection system serving the Galt STP receives contributions from a wide range of industrial sectors including metal finishers, textile mills, a pesticide manufacturer, food processing industries, foundries, electronics industries and chemical manufacturers. Major contributors are identified in Table 13. Overall, it is estimated that about 26 percent of the plant influent is contributed from industrial sources.

Table 13
MAJOR INDUSTRIAL CONTRIBUTORS TO THE GALT STP

Company	SIC	Annual Sanitary Sewer Discharge (m^3)
Bibby Foundry	3321, 3293	146,016
Ciba - Geigy	2879	8,580
COM DEV	3661	5,000
Croydon Furniture	2521, 2522, 2531	4,699
Dresser Canada	3536, 3545, 3494, 3829	5,083
Electrohome	3621	26,279
Franklin Mfg. Co.	3632, 3633	94,758
Galt British Forge	3321	29,705
Hoechst Canada	3555, 3079	120,444
Mitten Industries	3469	214,726
Montreal Woolens	2231, 2221	47,862
Newland Textiles	2258, 2231	185,574
Reuter - Stokes	3829, 3823	9,373
Tiger Brand Knitting	2254, 2253	283,350
Walker Exhausts	3714	19,147
Coutrice Steel	3312	38,904
Canadian General Tower	2295, 3079, 3069, 2392, 2391	15,017
Allen Bradley	3622	57,977
Babcock & Wilcox	3569, 3443	30,239
Cambridge Brass	3432, 3494	17,417
Canparts	3714	10,658
Inglis	3633	159,651
Industrial Processing	3471	43,460
Long Manufacturing	3443	63,700
Canadian Tack & Nail	3399, 3964, 2241	6,279
Windsor Wafers	2052	17,124
Cambridge Towel	2211	355,578
Total		1,816,600

(KIR21/272W)

Digested sludges from the Cambridge STP are applied to agricultural land and meet MOE guidelines for metal content. Despite the high industrial contribution to the plant, only the cadmium content of the sludge approaches the land application guidelines based on 1985 average data presented in Table 14.

Table 14
METAL CONTENT OF GALT STP SLUDGES

	Wet Sludge Concentration		Nitrogen/Metal Ratio		Ontario Guideline Limit for Metal Ratios
Parameter	Mean (mg/L)	Std. Dev.	Mean	Std. Dev.	
Chromium	20	7	58	22	6
Zinc	51	17	23	10	4
Copper	43	14	21	11	10
Nickel	7	4	169	86	40
Lead	12	17	162	72	15
Cadmium	3	1	560	337	500
Cobalt	0.2	0.1	8,367	3,076	50
Mercury	0.09	0.05	12,892	3,654	1,500
Molybdenum	0.4	0.1	8,259	1,005	180
Arsenic	0.3	0.08	4,397	1,536	100
Selenium	0.1	0.03	10,509	3,482	500

2.2 Sampling Procedures

Sampling procedures were similar at each of the three STPs included in the program. Grab samples of the influent to the plant and the treated secondary effluent from the plant were collected a 2-hour intervals for a period of about 200 hours to provide an influent and effluent sequence of approximately 100 paired data points. All samples were collected in stainless steel, glass or teflon containers and appropriately preserved onsite prior to analysis. Samples which were destined for analysis of soluble components (filtered TOC, filtered phosphorus) were filtered onsite immediately after collection.

In addition to the influent and effluent samples collected for trace contaminant analysis, mixed liquors and waste activated sludges were sampled at eight hour intervals to allow solids retention time (SRT) calculations.

Influent and secondary effluent samples for acute toxicity testing were also collected at the same locations as those for chemical analyses. A total of ten influent and secondary effluent samples were collected over the eight-day monitoring period to cover periods of high load (high strength and high flow during day-time weekday periods) and lower load(early morning and/or weekend periods). In addition to these samples, the combined final effluent from the facility after chlorination was also sampled for toxicity testing on 14 occasions. These samples were typically collected twice per day in the early morning (04:00 hours) and around mid-day (10:00 to 12:00).

Specific details of the sampling program at each facility are presented in the following subsections.

2.2.1 Waterloo STP

The intensive sampling at the Waterloo STP was conducted for 8 days in July 1986, commencing on July 2 at 12:00 hours and finishing on July 10 at 16:00 hours.

Raw sewage samples were collected downstream of the degritters in the old part of the plant (Stage I). This sample was considered to be representative of the total STP influent. The sample point was upstream of the point of supernatant return from the anaerobic digestion facilities and of the waste activated sludge discharge point. Secondary effluent samples were collected from the discharge of the secondary clarifiers in each of the two plants upstream of the point of chlorine addition to the Stage I plant effluent. The Stage I and Stage II Phase 1 plant effluents were combined in proportion to the relative flow through each plant. These sampling locations were identified in the plant schematic in Figure 1.

2.2.2 Welland STP

The intensive sampling at the Welland STP was conducted for 8 days in August 1986, commencing on August 19 at 08:00 hours and finishing on August 27 at 12:00 hours.

Raw sewage samples were collected downstream of the detritor. Digester supernatant flow was temporarily diverted by means of portable submersible pumps from the normal discharge point in the trunk sewer upstream of the plant influent wet well to a discharge point downstream of the raw sewage sample point. Thus, raw sewage samples collected during the intensive sample period did not contain digester supernatant. Secondary effluent samples were collected from the discharges of the old and new secondary clarifier and combined in proportion to the relative flow through each clarification section. Flows through the old and new clarifiers were estimated based on level measurements on the overflow weirs of the chlorine contactors serving each set of secondary clarifiers. These sample locations were identified on the plant schematic in Figure 2.

2.2.3 Galt STP

The intensive sampling at the Galt STP was conducted for 8 days in September and October 1986, commencing on September 30 at 08:00 hours and finishing on October 8 at 12:00 hours. Heavy rains were experienced during the early period of sampling on September 30.

Raw sewage samples were collected downstream of the No. 1 detritor. The sample point was downstream of the digester supernatant discharge; however, plant personnel had indicated that supernatant was not returned to the plant for treatment as the secondary digester was operated at a low level to prevent supernating. Unfortunately, on October 7, a timer activating the raw sludge pumps failed, causing an excessive amount of sludge to be pumped to the digesters. As a result, supernatant was returned to the plant. Raw sewage samples collected at 06:00 and 08:00 hours had noticeably high suspended solids content because of the presence of digester supernatant. Plant staff rectified the problem immediately thereafter.

Secondary effluent samples were collected from the common collection chamber serving the four secondary clarifiers upstream of the chlorine contactor. These sampling locations were identified on the plant schematic in Figure 3.

2.3 Analytical Procedures

A small number of selected trace contaminants were monitored to maintain analytical requirements at a manageable level. Conventional contaminants were also monitored so that STP performance during the sampling period could be compared to the historical performance data.

2.3.1 Conventional Contaminants

All influent and effluent samples were analyzed for filterable organic carbon (FOC), using an Astro Model 2000 TOC analyzer equipped with an autosampler, and for total suspended solids. Influent and effluent BOD_5 were measured on five to ten occasions over the eight day sampling period. Nitrogen species (TKN and NH_3-N) were also measured to assess the degree of nitrification achieved at the facility. In raw sewage samples, TKN was measured on approximately every second sample and ammonia was measured on every tenth sample. In effluent samples, ammonia was measured on every second sample and TKN was measured on five to ten occasions. In addition, mixed liquor samples and waste activated sludge samples were analyzed for total suspended solids (TSS) and volatile solids (VSS). All conventional analyses were conducted according to the procedures described in Standard Methods(8).

2.3.2 Metals

Six common heavy metals - cadmium, chromium, copper, nickel, lead and zinc - were selected for analysis in all influent and effluent samples. Analyses were conducted on unfiltered, pre-concentrated digested samples by inductively coupled plasma (ICP) techniques. As a result of this analytical approach, data were also generated on eighteen other metals, although these data were not subjected to detailed analysis as part of this investigation with the exception of the phosphorus concentration data in influent and effluent samples. Phosphorus was considered to be a conventional contaminant in the same class as the TOC and nitrogen species. To support the total phosphorus data generated along with the other metal data, filtered samples of all raw sewage and secondary effluents were also digested and analyzed specifically for filtered phosphorus by ICP procedures.

2.3.3 Organics

All influent and effluent samples were analyzed for total phenolic compounds wet chemically using the 4-aminoantipyrine (4-AAP) method as described in Standard Methods(8).

Polyaromatic hydrocarbons (PAH) were analyzed in all influent and effluent samples at the Waterloo STP by reverse phase high pressure liquid chromatography (HPLC) with UV and fluorescence detection according to the U.S. Environmental Protection Agency Method 610. Samples for PAH analysis were extracted in dichloromethane in the field in a continuous liquid-liquid extractor as described by Neilson et al(9). At the Welland STP, all influents and effluents were sampled and extracted for PAH analysis. However, since the Waterloo STP results suggested that PAHs were typically not detected, only 10 influent and 10 effluent extracts were initially analyzed to define the need for additional analyses. As concentrations were generally at or below the detection limit in all samples, the additional extracts were not analyzed. At Galt STP, all samples were extracted for PAH analyses. However, only 33 influent sample extracts and 35 effluent sample extracts were analyzed to maximize resources.

Volatile organics in influent and effluent samples were analyzed using the purge and trap gas chromatographic (GC) procedure with dual electron capture detector (ECD) and flame ionization detector (FID) according to EPA Method 601 (purgeable halocarbons) and Method 602 (purgeable aromatics). Samples were introduced to the GC through an autosampler. Excluded from the volatile organics analysis were the low boiling point compounds vinyl chloride, chloromethane, bromomethane, chloroethane, trichlorofluoromethane and 1,1-dichloroethylene. These compounds are seldom detected in municipal wastewaters or STP effluents and, when detected, occur at low concentrations(4). Xylene isomers (o-xylene and p & m-xylene) were added to the compounds quantified by Method 602 since their presence had consistently been observed in Ontario municipal STPs(4). Due to an equipment malfunction only the FID capabilities of the GC were available for analysis of samples from the Waterloo STP.

2.3.4 Quality Control

A comprehensive quality control program was incorporated into all analytical work. In the case of conventional contaminants, metals and phenolics, the quality control involved field duplicates and field spikes which accounted for 10 percent of all samples submitted. In the case of PAH analyses, terphenyl was added to each sample prior to extraction to serve as a surrogate measure of recovery and matrix interference during analysis. Ten percent duplicate samples were also carried through the extraction and analysis procedure.

Because of concerns regarding the GC analysis procedures for volatile organics, 10 percent field duplicates were analyzed by the GC method and 30 percent of all samples collected at Waterloo STP were analyzed by an independent laboratory using gas chromatography - mass spectroscopy (GC-MS) procedures according to EPA Method 624. Good agreement between the GC and GC-MS results was achieved and in subsequent sampling at Welland and Galt, a reduced number of comparisons were done using the GC-MS to verify the GC results.

Results of the comparative GC-MS and GC analyses are presented in Appendix 1.

2.4 Biomonitoring Procedures

Influents, secondary effluents and chlorinated final effluents were subjected to toxicity testing with rainbow trout and *Daphnia magna*. The fish toxicity bioassays were 96-hour static acute toxicity tests conducted according to procedures outlined by Environment Canada(10) and the Ontario Ministry of the Environment(11). Forty-eight hour static bioassays with *Daphnia* followed the general directions of the EPA testing protocol(12) with specific modifications as described by Buikema *et al*(13).

In the case of chlorinated final effluent samples, the samples were dechlorinated with sodium sulphite prior to testing. The ammonia content of the chlorinated effluent samples was measured and, if toxicity was noted, it was intended to remove ammonia from the samples by filtration through clinoptilolite. Further details regarding the biomonitoring procedures are included in Appendix 2, along with a technical review of the literature related to toxicity monitoring of municipal STP effluents. The biomonitoring tests were conducted by BEAK CONSULTANTS LIMITED of Mississauga, Ontario.

3.0 WATERLOO STP RESULTS

3.1 Plant Operation and Performance

During the intensive sampling period at the Waterloo STP (July 2 to July 10), operating conditions and performance were representative of typical historic plant conditions. The only untoward event was the failure of the integrater/totalizer on the flow meter to the old part of the plant between 20:00 hr on July 6 and 08:00 hr on July 7. During this period, the ferrous chloride feed to the plant aeration tanks stopped because the chemical metering pumps were flow-paced from the flow meter signal. Because of the lack of flow data for this period, flow to the old plant was estimated based on the typical ratio of total plant flow to new plant flow of 1.0:0.4. This proportionality was also used to composite the secondary effluent samples from the two sections of the plant during this time period.

Flow data and influent and effluent quality data for the period of June 30 to July 13 encompassing the intensive sampling period are presented in Table 15. These data are based on plant monitoring records and are indicative of typical performance based on a comparison to the historic data (Table 2). Average flow during the two-week period was 39,350 m^3/d, compared to the historic average (Sept. 1985 to Sept. 1986) of 44,680 m^3/d. Maximum daily flow was 45,250 m^3/d.

Table 15
WATERLOO STP PERFORMANCE
(June 30 - July 13, 1988)

Average Daily Flow (m^3/d)	39,350
Influent Quality	
BOD_5 (mg/L)	213.
TSS (mg/L)	486.
TP (mg/L)	7.3
Effluent Quality	
BOD_5 (mg/L)	5.
TSS (mg/L)	7.
TP (mg/L)	1.04

The elevated effluent total phosphorus concentration is skewed by one high result (3.9 mg/L on July 7) which was directly attributable to the loss of ferrous chloride feed to the system on July 6 and 7.

Average operating conditions for the plant during the two week period encompassing the intensive sampling period are summarized in Table 16. These are considered typical based on historic operating data (Table 3).

Table 16
AVERAGE OPERATING CONDITIONS AT WATERLOO STP
(June 30 - July 13, 1986)

	Stage I	Stage II - Phase 1
MLSS (mg/L)	1960	1786
MLVSS (%)	73.1	73.8
F/M (kg/kg VSS.d)	0.26	0.23
SRT (d)	6.3	8.1
DO Range (mg/L)	1.5 - 3.3	0.9 - 4.0
SVI	344	230

3.2 Intensive Sampling Program Results

3.2.1 Conventional Contaminants

A frequency distribution for the total plant flow recorded at two-hour intervals at the Waterloo STP during the 200 hour sampling period is presented in Figure 4. The distribution was log-normal with a median value of 39,700 m^3/d and showed a typical diurnal variation as indicated by the chronological plot in Figure 5.

Frequency distributions of influent and effluent FOC, influent TKN and effluent NH_3-N, influent and effluent TSS, and influent and effluent total and filtered phosphorus are presented in Figures 6 to 10, respectively. Key statistical data for these conventional contaminants are summarized in Table 17. Average effluent quality measured during the intensive sampling confirmed plant measurements in terms of

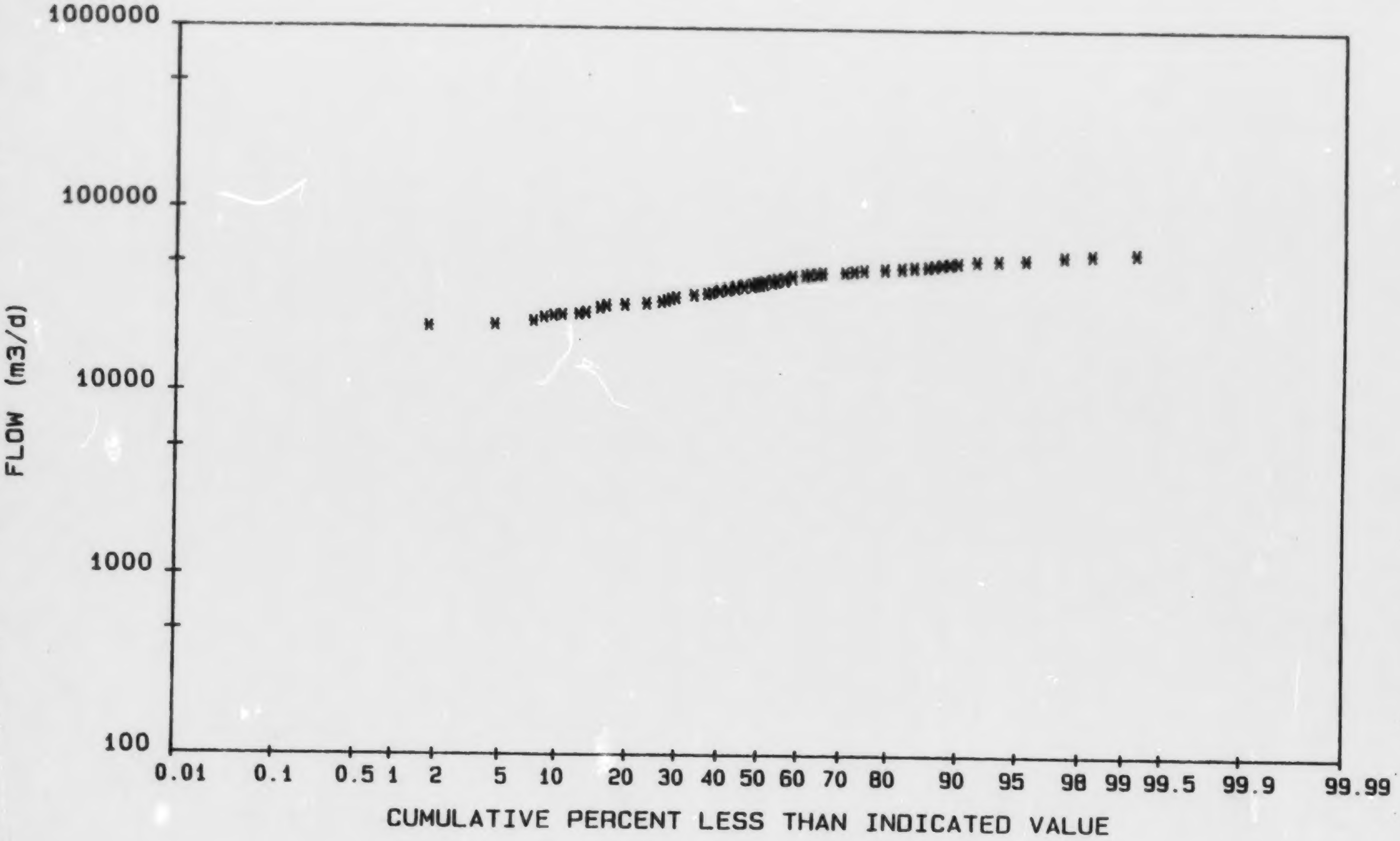

FIGURE 4: PROBABILITY DISTRIBUTION OF FLOW DATA AT WATERLOO STP

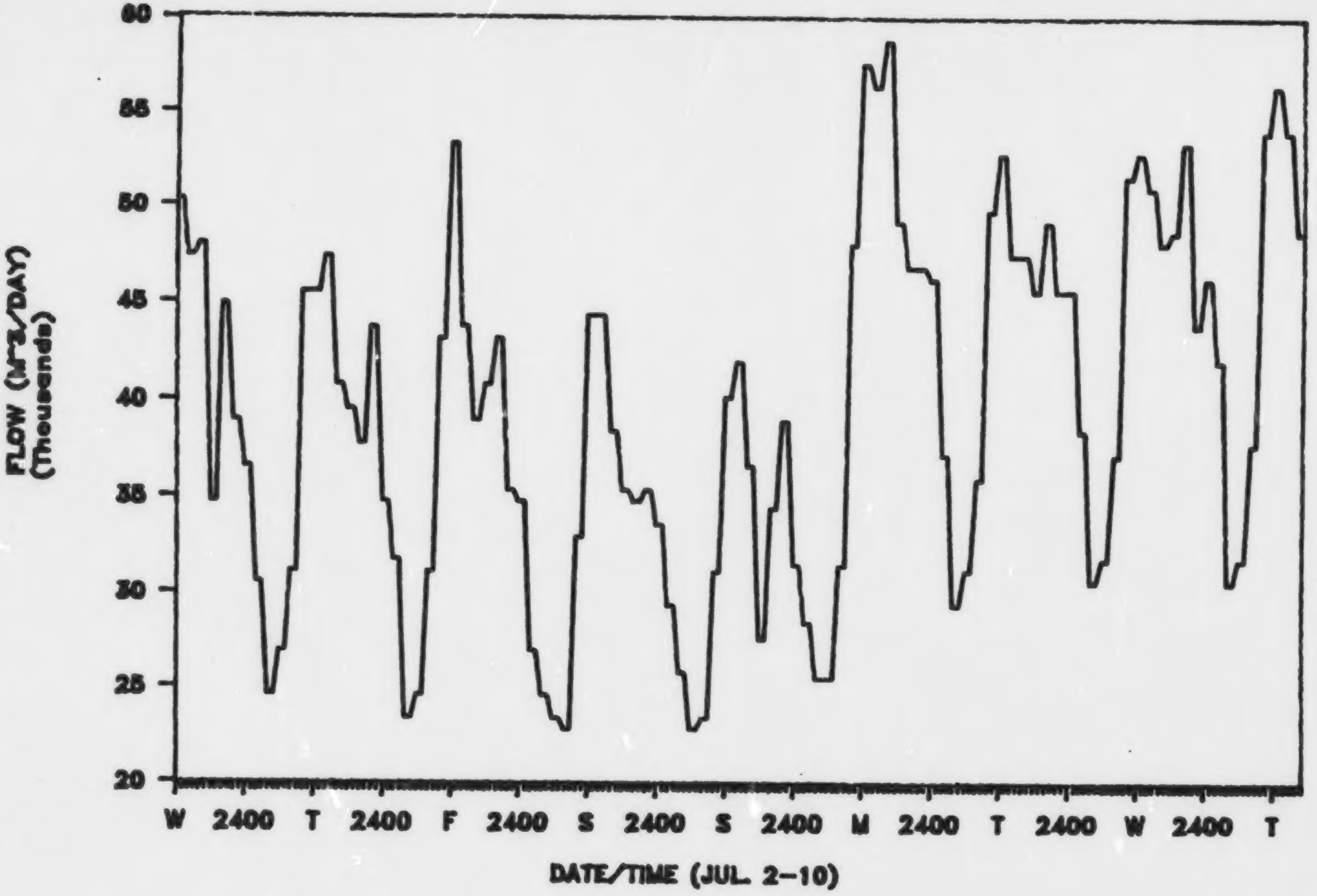

FIGURE 5: CHRONOLOGICAL FLOW PATTERN AT WATERLOO STP

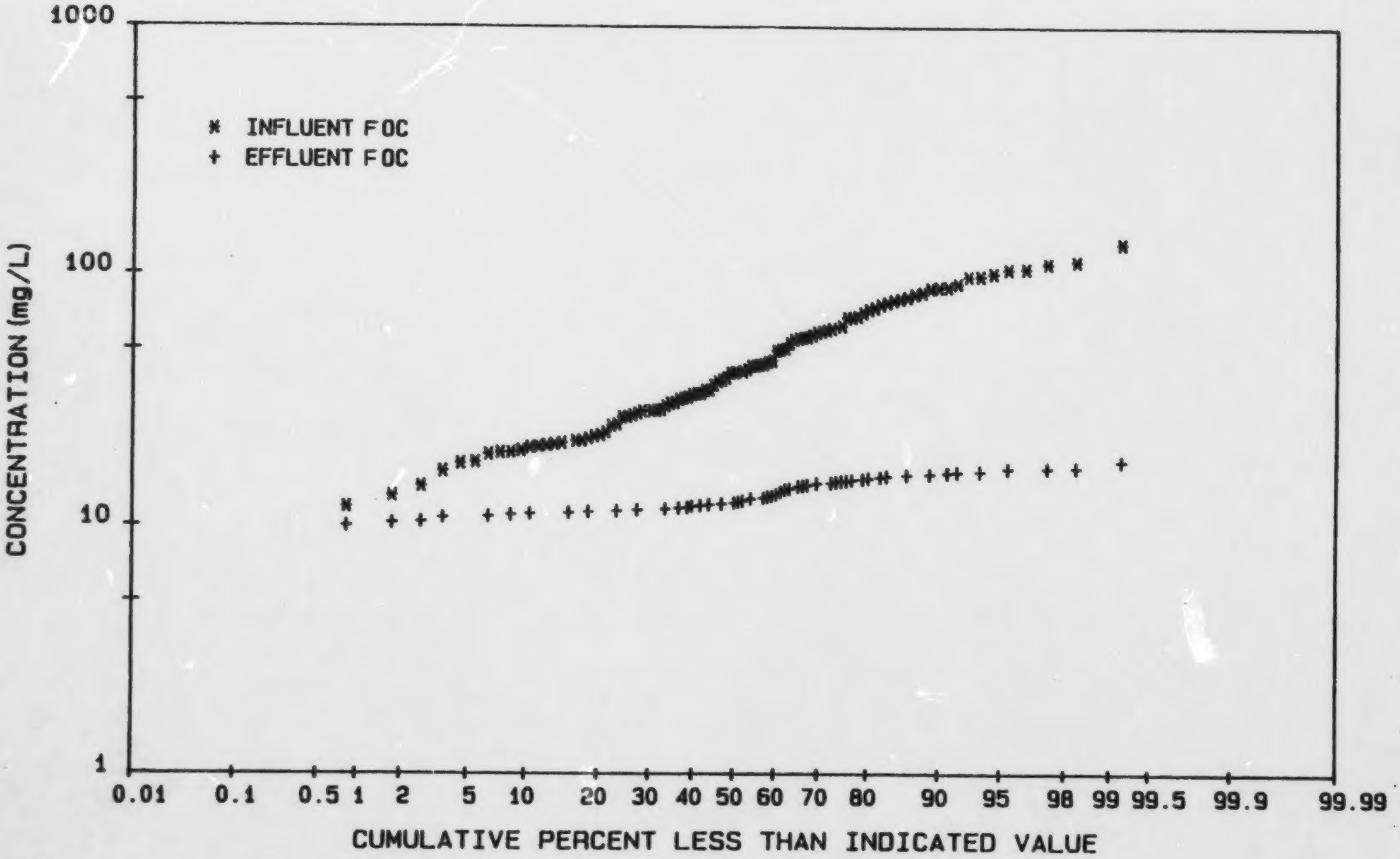

FIGURE 6: PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FOC CONCENTRATION AT WATERLOO STP

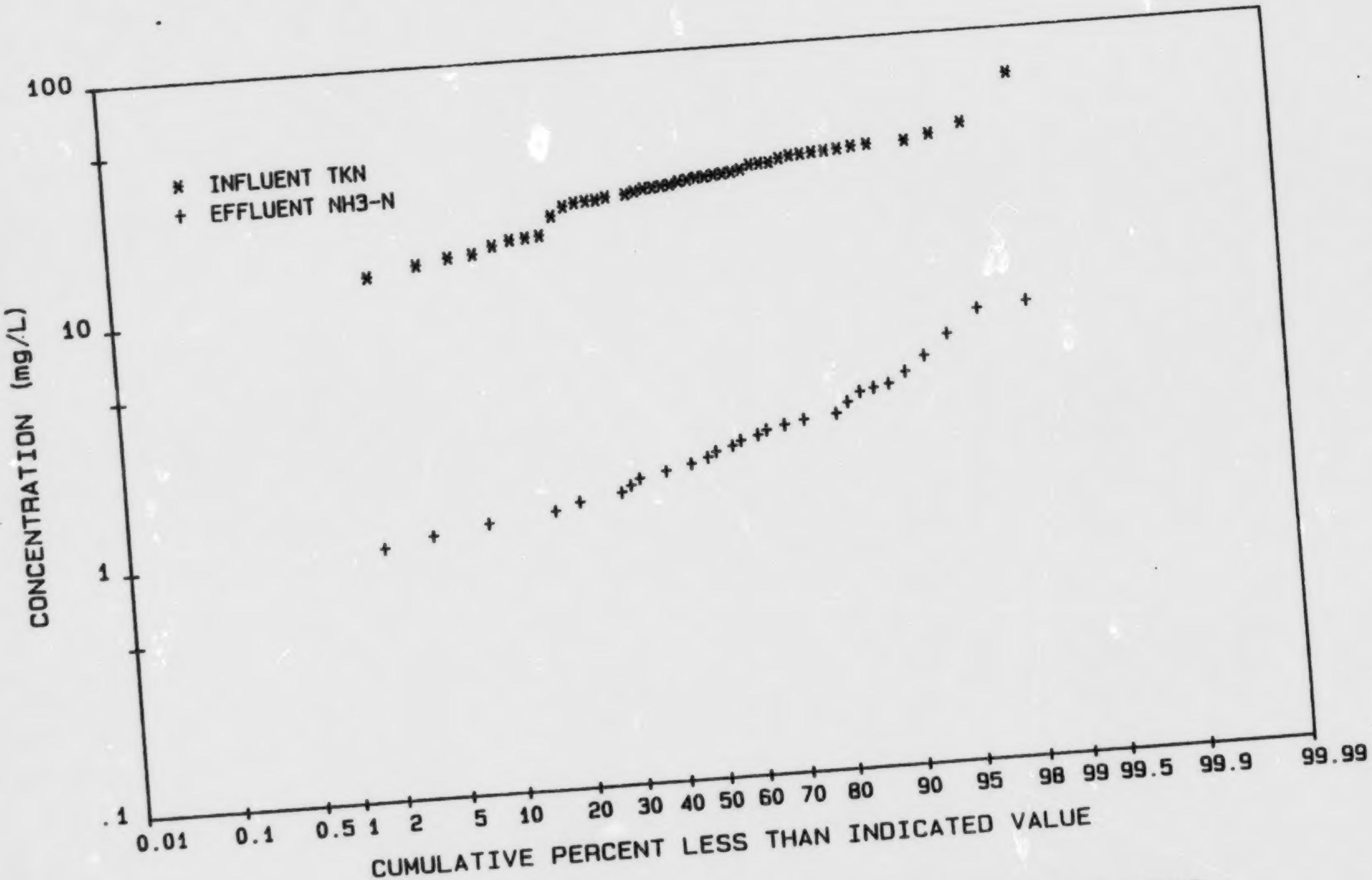

FIGURE 7 PROBABILITY DISTRIBUTION OF INFLUENT TKN AND EFFLUENT AMMONIA CONCENTRATION AT WATERLOO STP

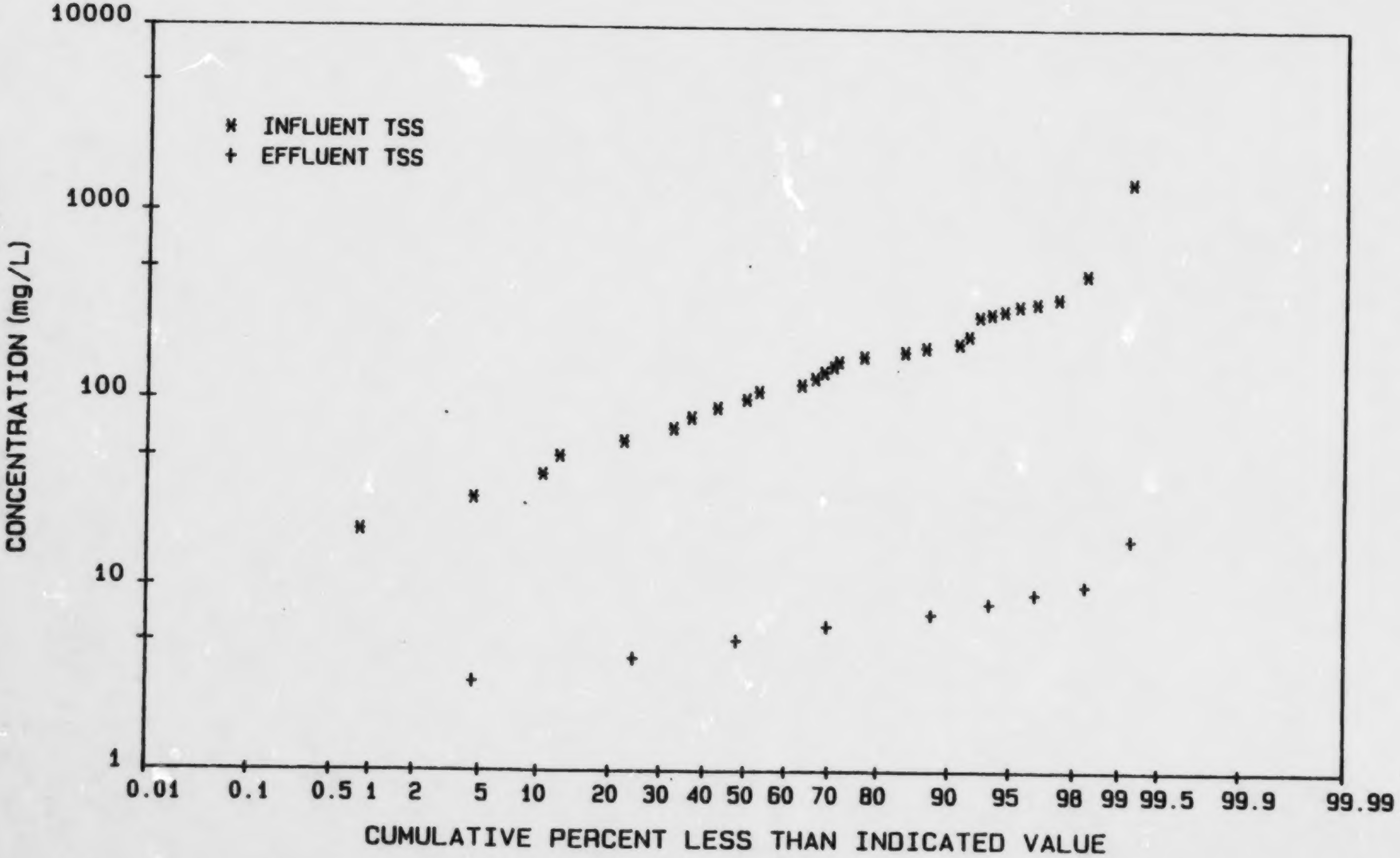

FIGURE 8 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TSS CONCENTRATION AT WATERLOO STP

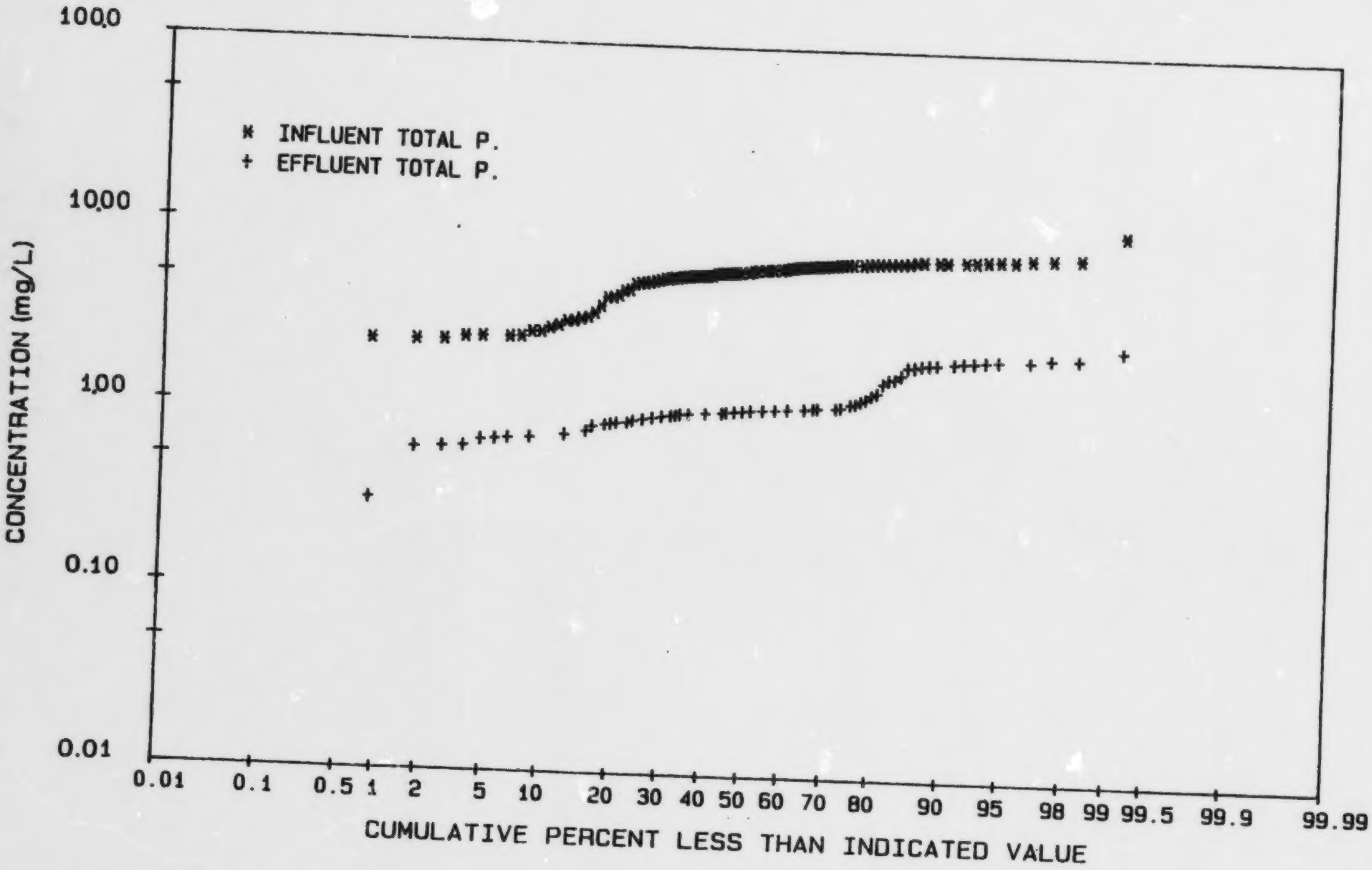

FIGURE 9 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOTAL PHOSPHORUS CONCENTRATION AT WATERLOO STP

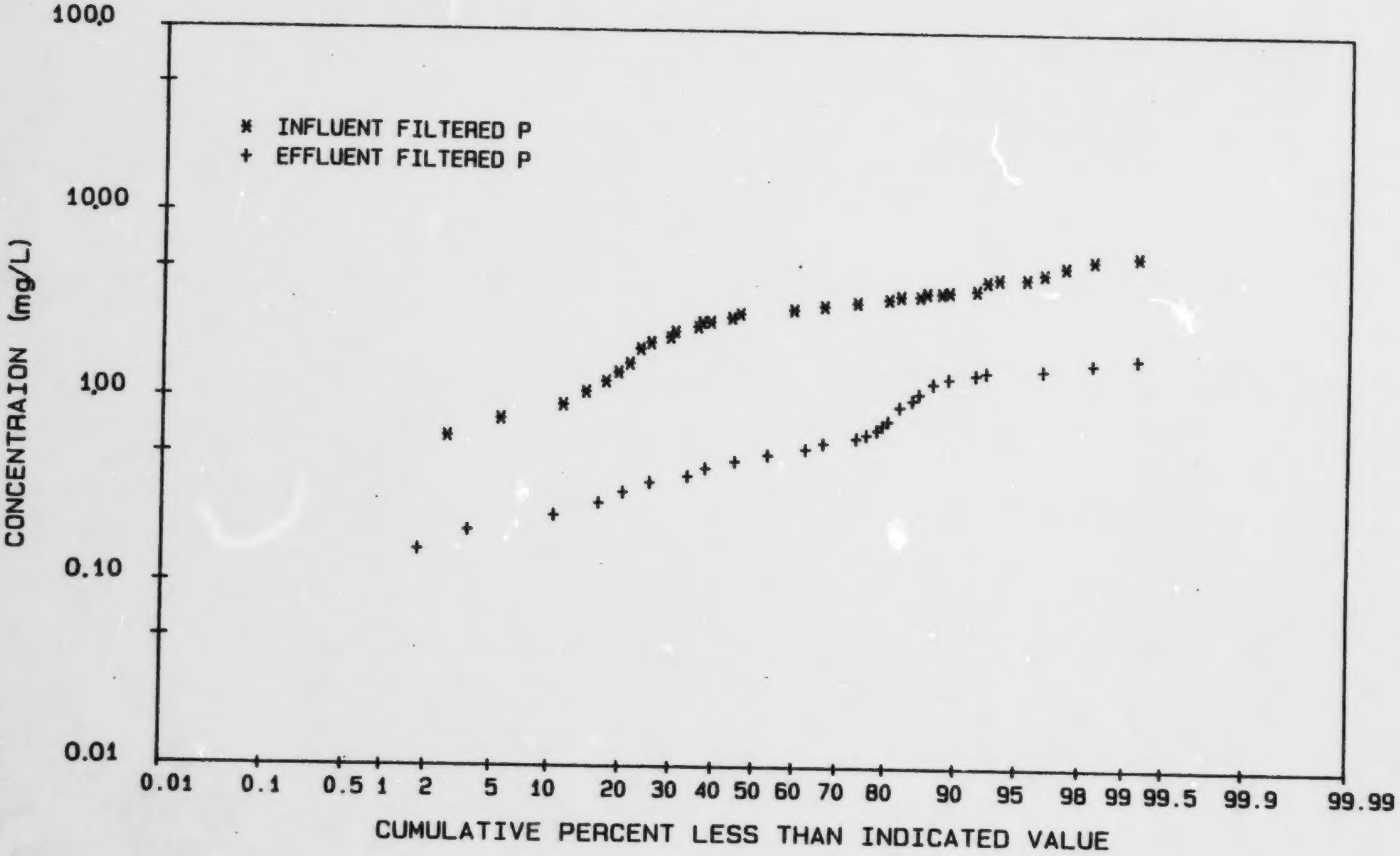

FIGURE 10 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FILTERED PHOSPHORUS CONCENTRATION AT WATERLOO STP

Table 17
CONVENTIONAL CONTAMINANT DATA FOR WATERLOO STP

	Influent						Effluent					
Parameter*	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
BOD_5	9	110.	130.9	67.5	51.6	-	10	4.7	5.0	1.6	32.0	-
FOC	99	40.9	48.0	27.5	57.3	105	99	13.0	13.2	2.1	15.9	16.8
TSS	99	105.	137.	157.	115.	308	99	5.5	5.8	2.0	34.5	9.1
TP	99	5.35	5.65	1.64	29.0	7.46	99	1.07	1.15	0.46	40.0	2.10
Filt. P	99	2.45	2.78	1.20	43.2	4.62	99	0.52	0.61	0.39	63.9	1.46
TKN	45	27.6	28.8	8.47	29.4	-	5	2.50	2.58	0.55	21.3	-
NH_3-N	11	16.6	16.8	2.38	14.2	-	49	2.20	2.47	1.39	56.3	-

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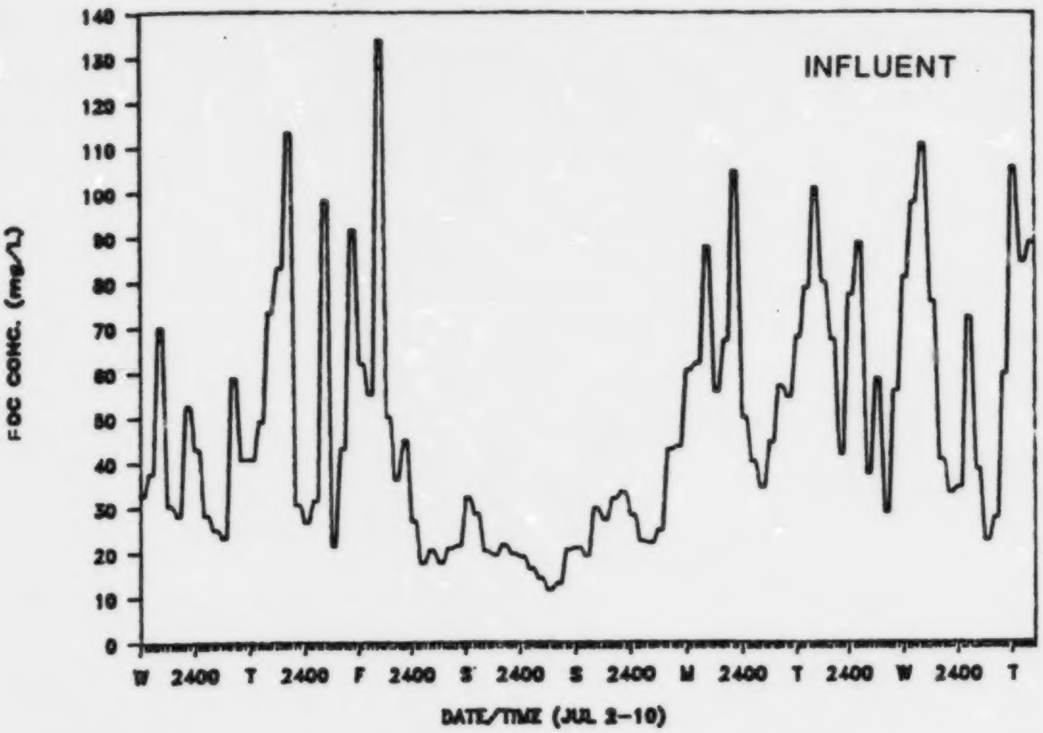
*All concentrations reported in mg/L. RSD reported as %.

BOD_5, TSS and phosphorus. The data also indicate that a significant amount of nitrification was occurring in the plant during the sampling period, with effluent NH_3-N concentrations averaging approximately 2.5 mg/L compared to influent TKN levels of near 30 mg/L. An anomaly exists in the influent TSS concentrations which, according to the intensive data, averaged 137 mg/L compared to a plant reported average of 486 mg/L. Data collected at the Waterloo STP during the MISA 40 STP program(41) also suggest lower TSS raw sewage concentrations than typically reported at the plant. Based on 5 days of sampling in January 1987 and 5 days in July 1987, the average influent TSS concentration was 124 mg/L. Discussions with plant staff regarding sampling and analytical procedures indicate that the plant sampling location was changed in 1987 because it was felt that a non-representative raw sewage sample containing elevated TSS concentrations was being obtained. Since that change significantly lower raw sewage TSS concentrations have been reported by the plant.

As illustrated in Figures 11 and 12 both the organic strength, measured as FOC, and the TSS content of the raw sewage exhibited a typical diurnal pattern with reduced concentrations on weekends as compared to weekdays. These diurnal characteristics were not apparent in the effluent. Influent total and filtered phosphorus (Figures 13 and 14, respectively) showed the same diurnal trends; however, the impact of ferrous chloride feed interruption on both total and filtered phosphorus concentrations in the effluent is readily apparent along with the rapid response of the system after the chemical dosage was re-established.

3.2.2 Metals

Probability distributions for influent and effluent concentrations of cadmium, chromium, copper, nickel, lead and zinc are presented in Figures 15 to 20, respectively. Key statistics describing these distributions are summarized in Table 18. Copper and zinc were present in the raw wastewater at the highest concentrations, in excess of 100 µg/L. Chromium, nickel and lead were present at lower concentrations in the 10 to 50 µg/L range and cadmium concentrations averaged less than 5 µg/L.



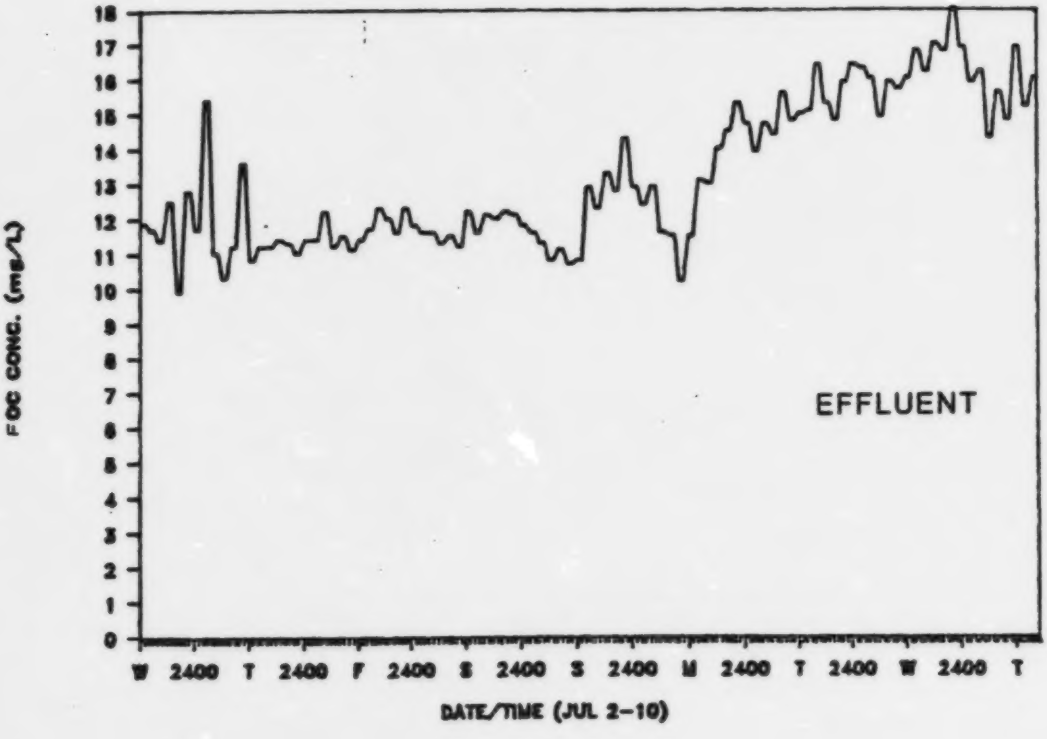
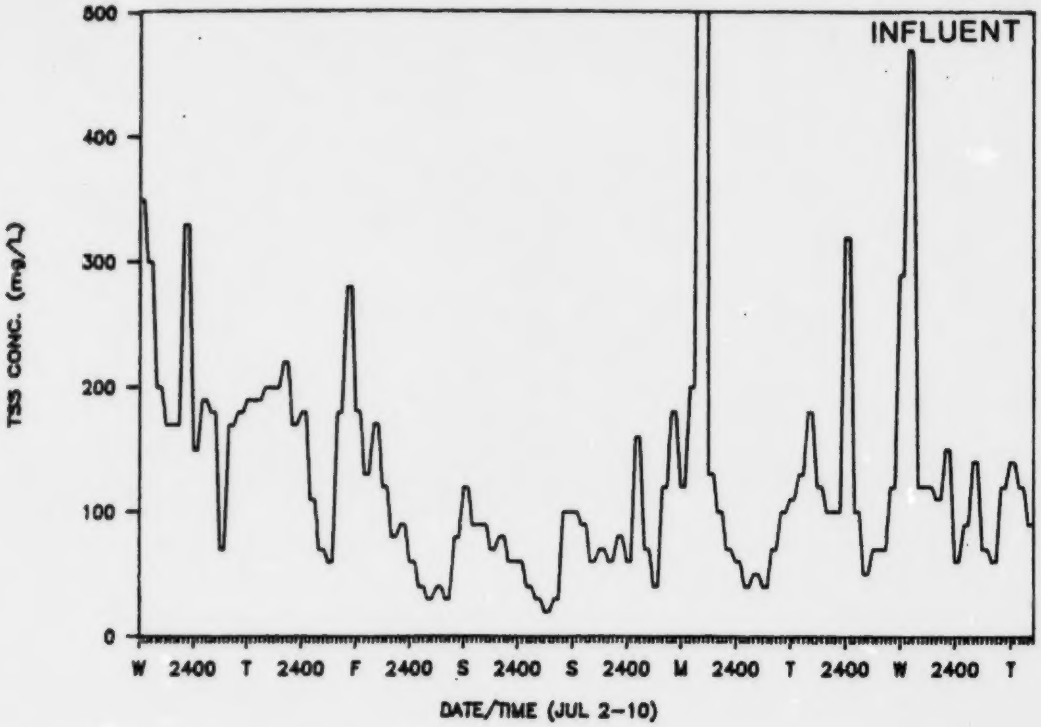


FIGURE 11: CHRONOLOGY OF INFLUENT AND EFFLUENT FOC AT WATERLOO WPCP



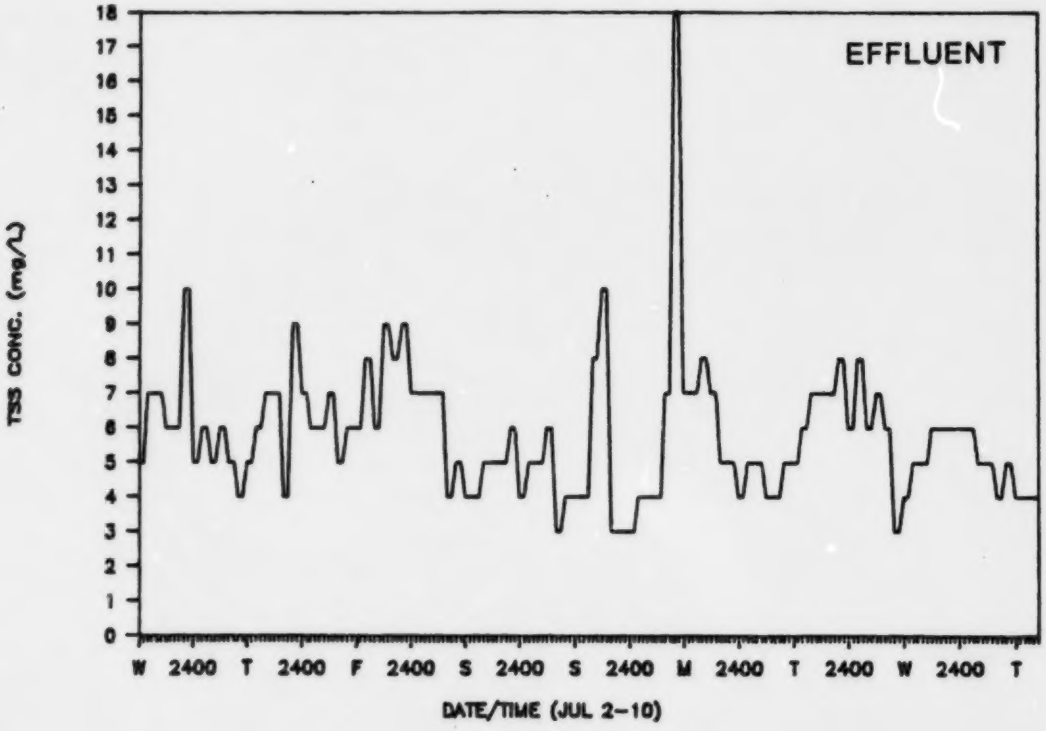


FIGURE 12: CHRONOLOGY OF INFLUENT AND EFFLUENT TSS AT WATERLOO WPCP

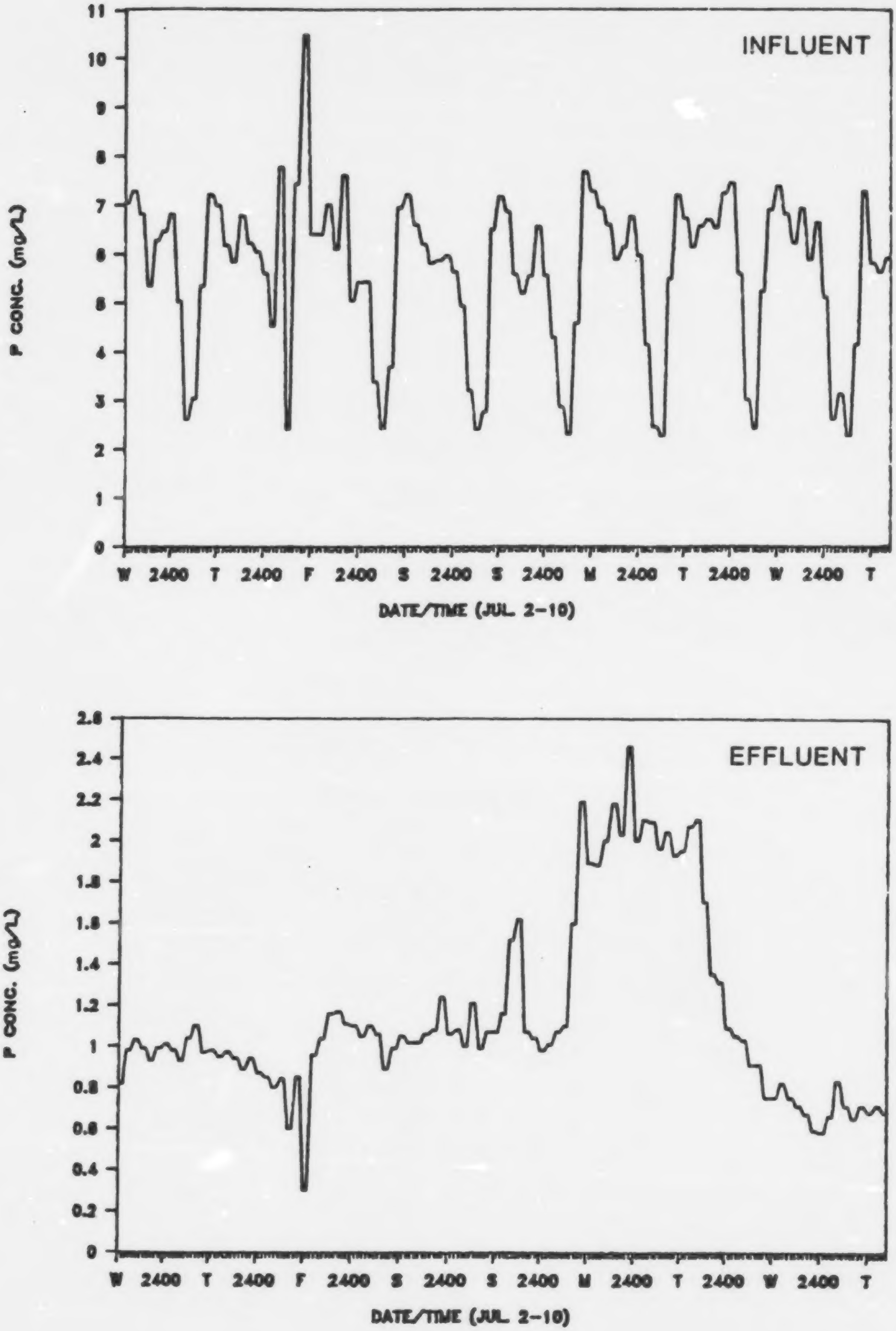


FIGURE 13: CHRONOLOGY OF INFLUENT AND EFFLUENT P

AT WATERLOO WPCP

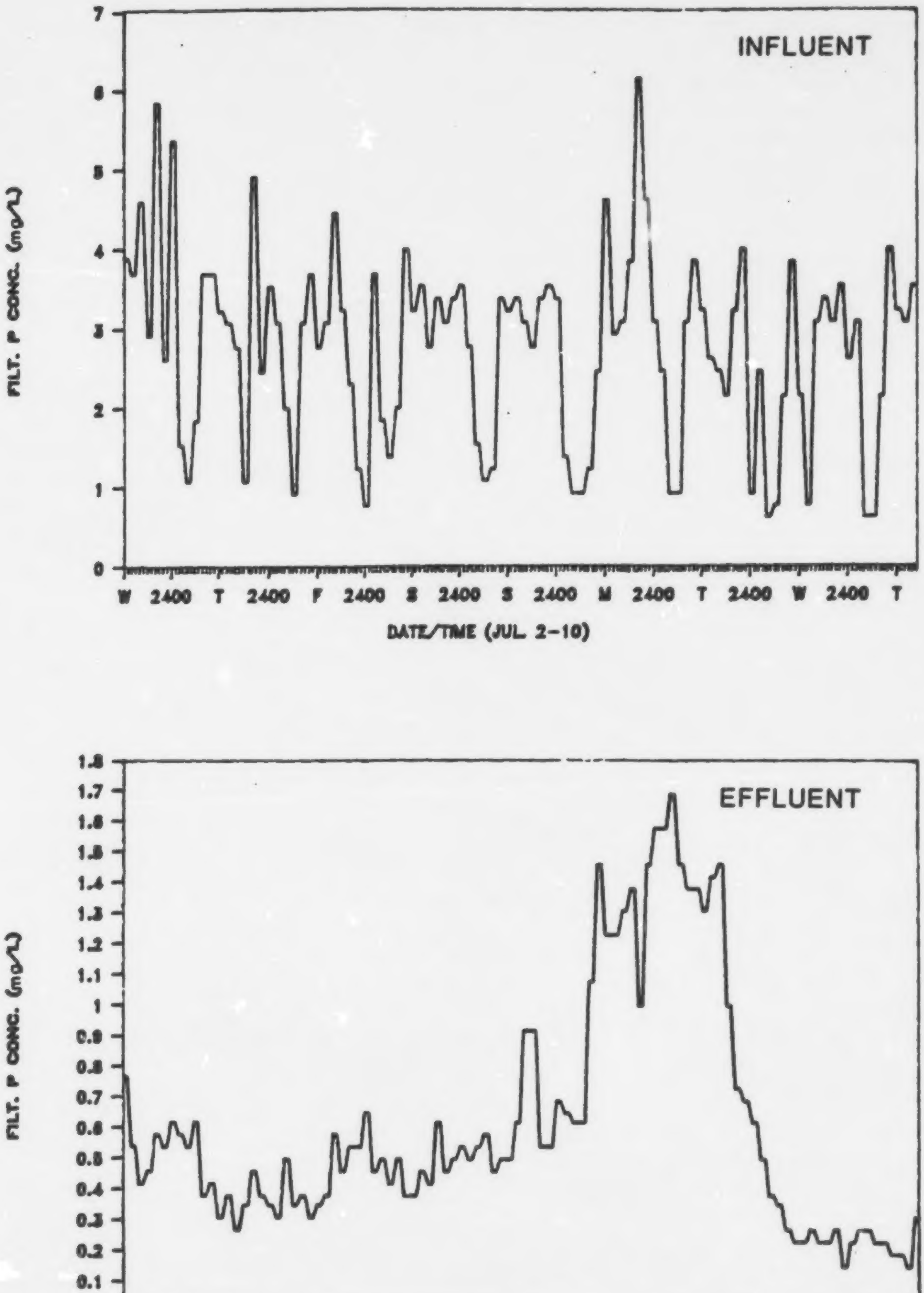


FIGURE 14: CHRONOLOGY OF INFLUENT AND EFFLUENT FILT. P AT WATERLOO WPCP

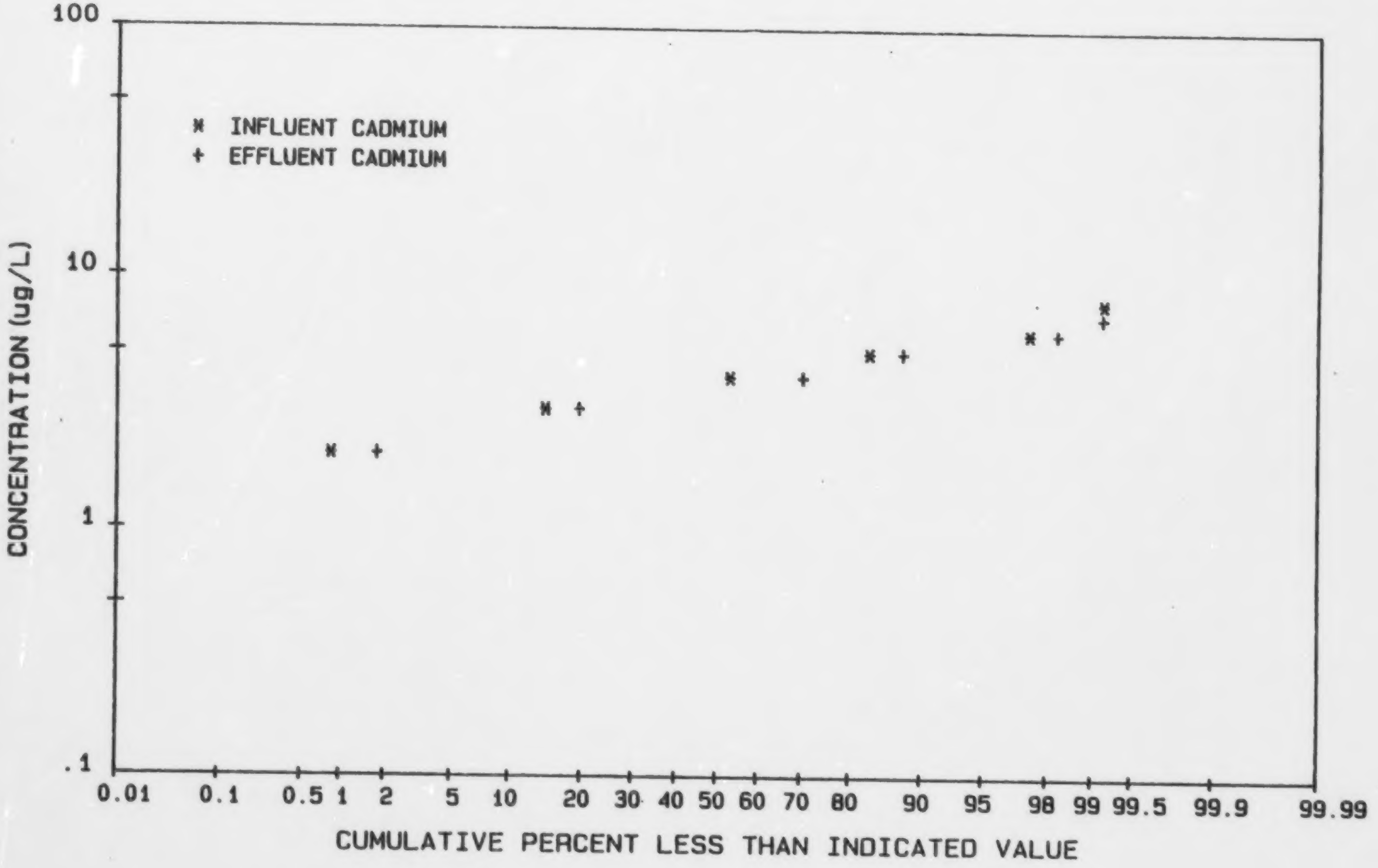


FIGURE 15 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CADMIUM CONCENTRATION AT WATERLOO STP

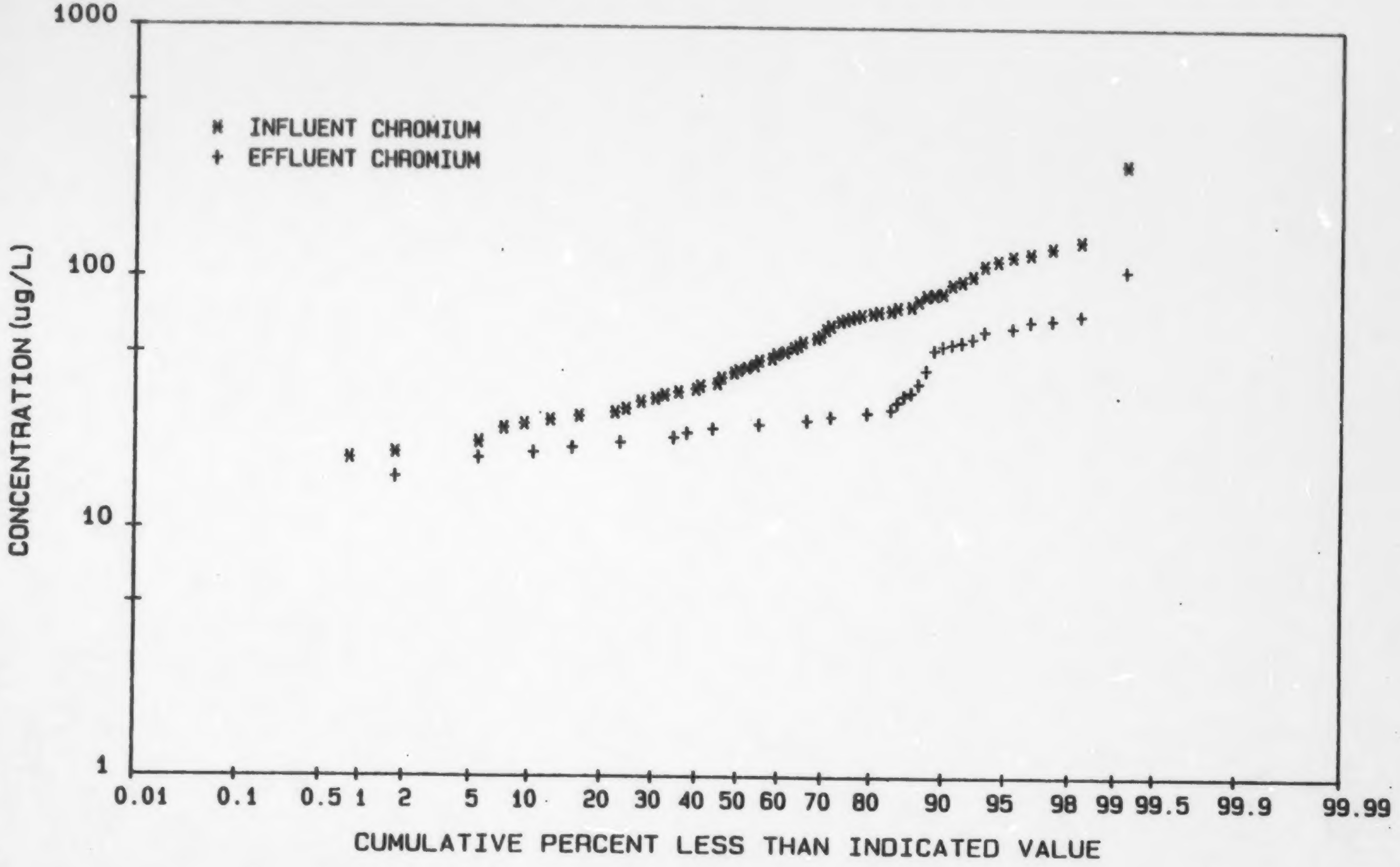


FIGURE 16 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHROMIUM CONCENTRATION AT WATERLOO STP

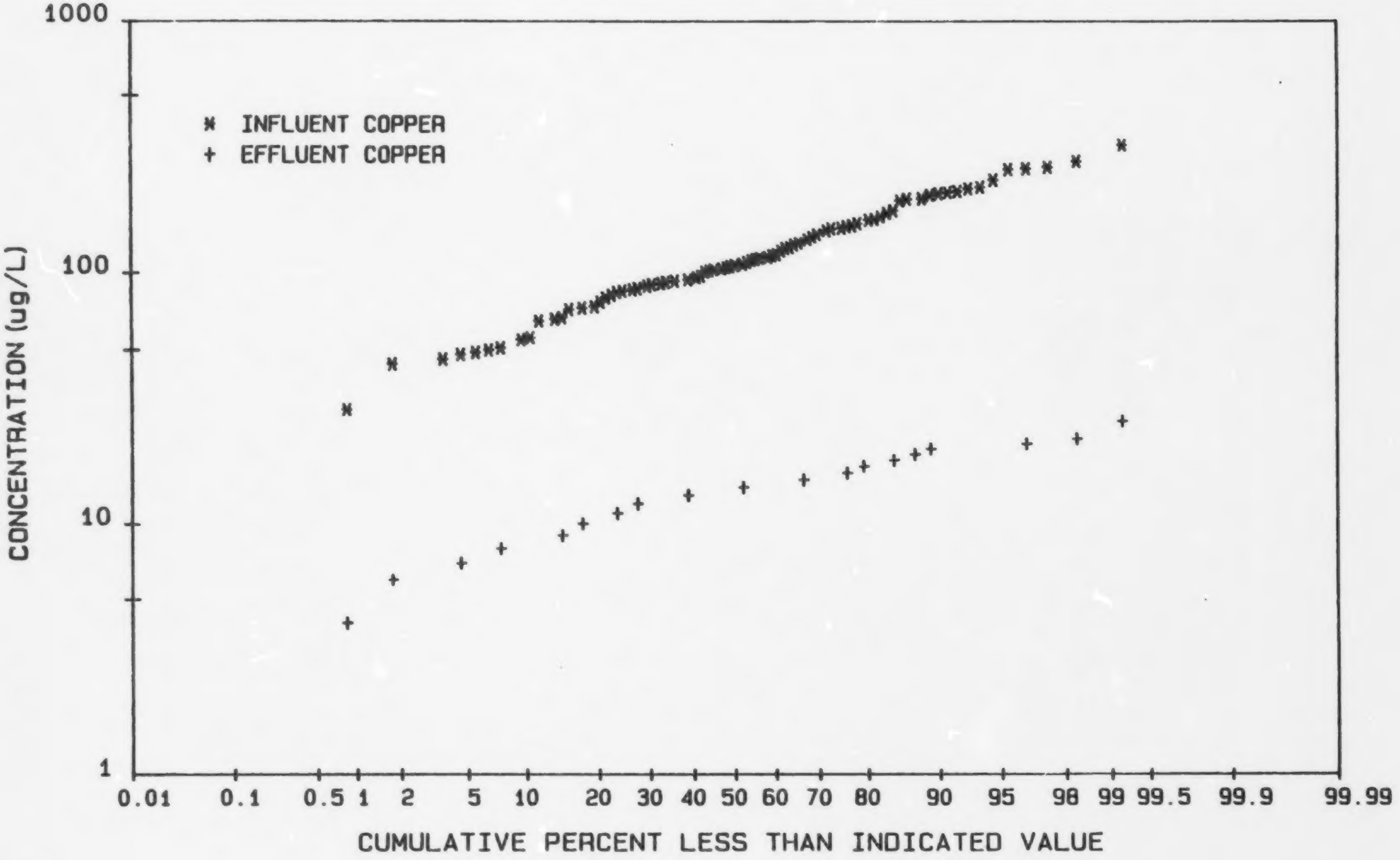


FIGURE 17 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT COPPER CONCENTRATION AT WATERLOO STP

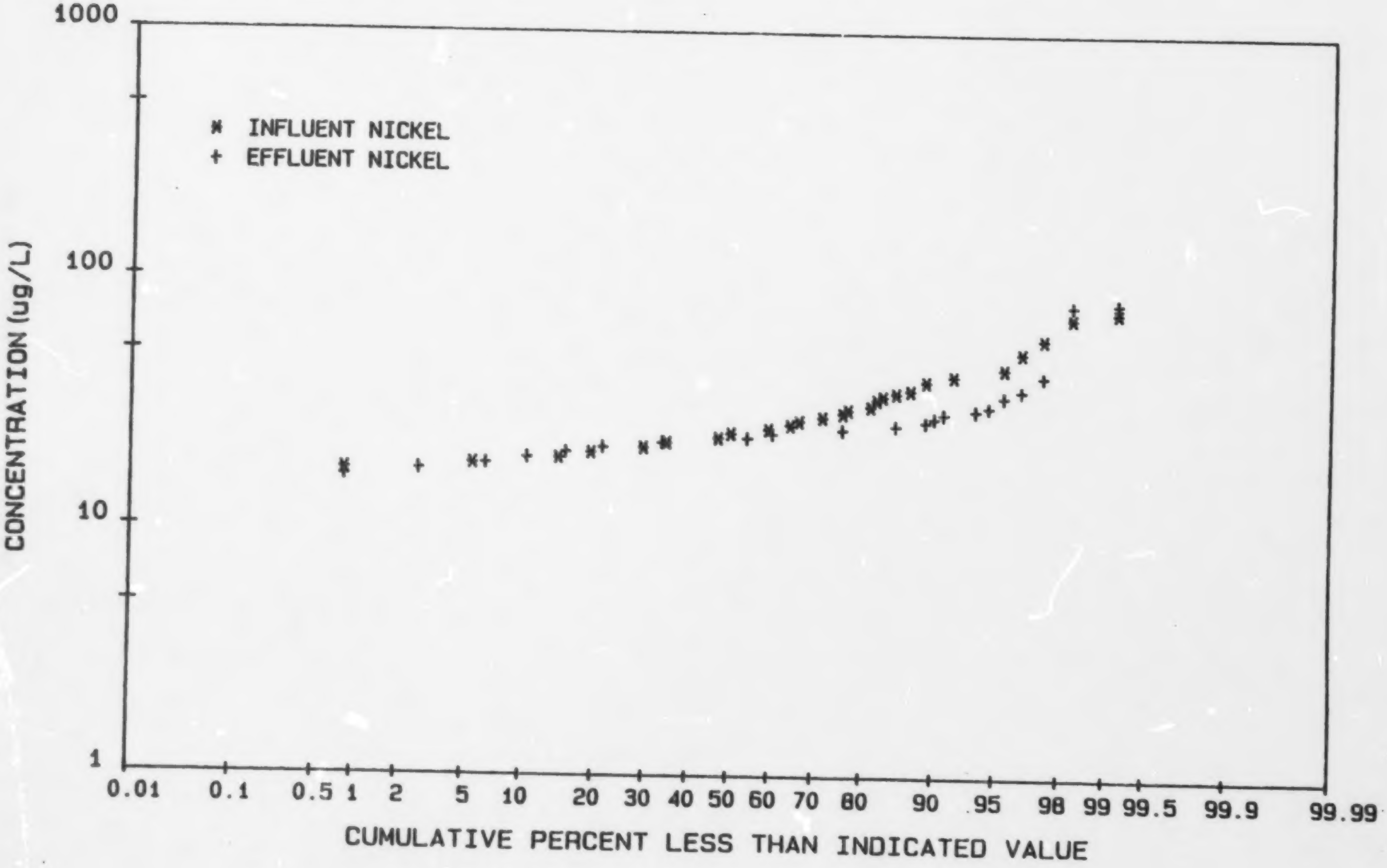


FIGURE 18 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT NICKEL CONCENTRATION AT WATERLOO STP

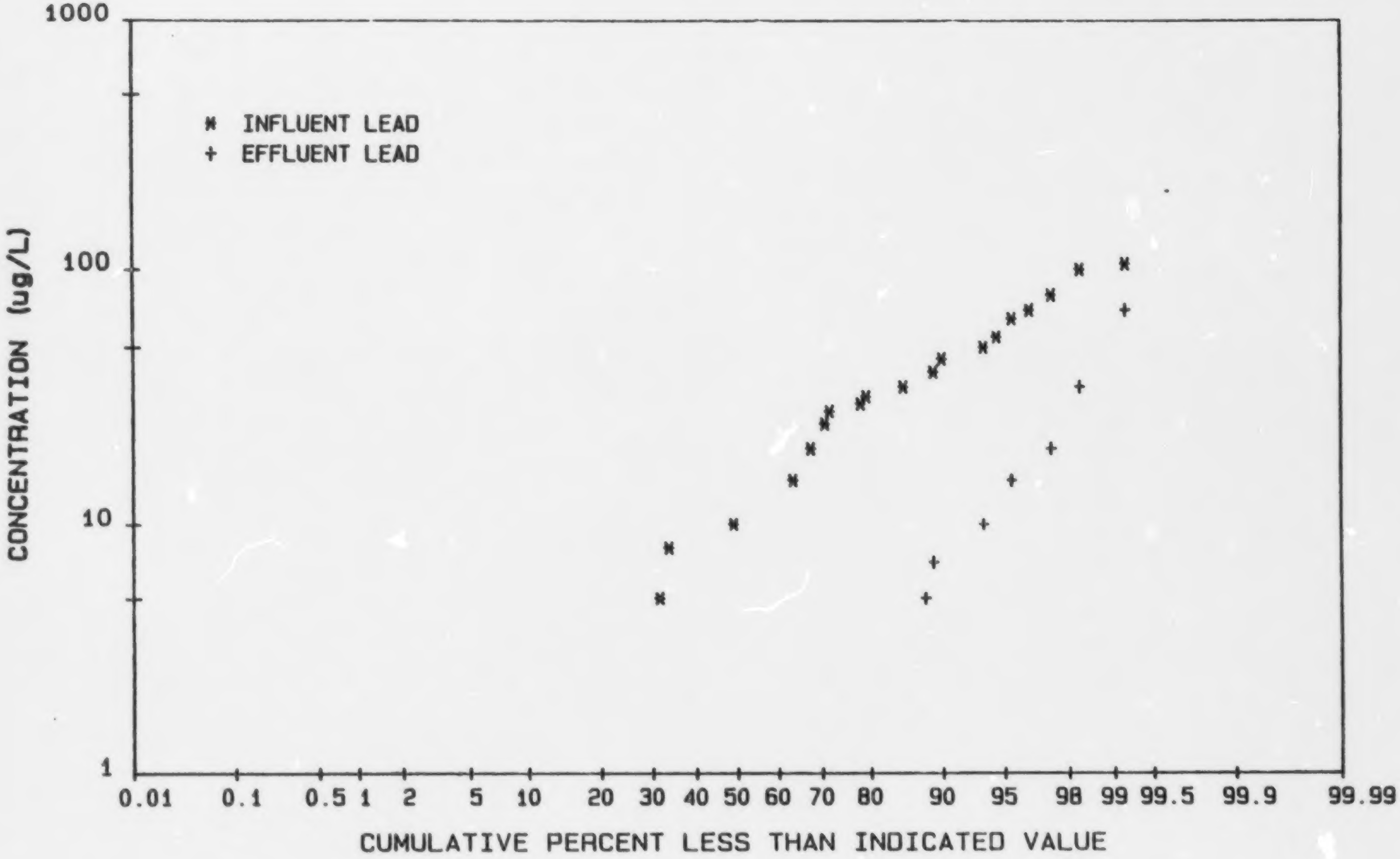


FIGURE 19 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT LEAD CONCENTRATION AT WATERLOO STP

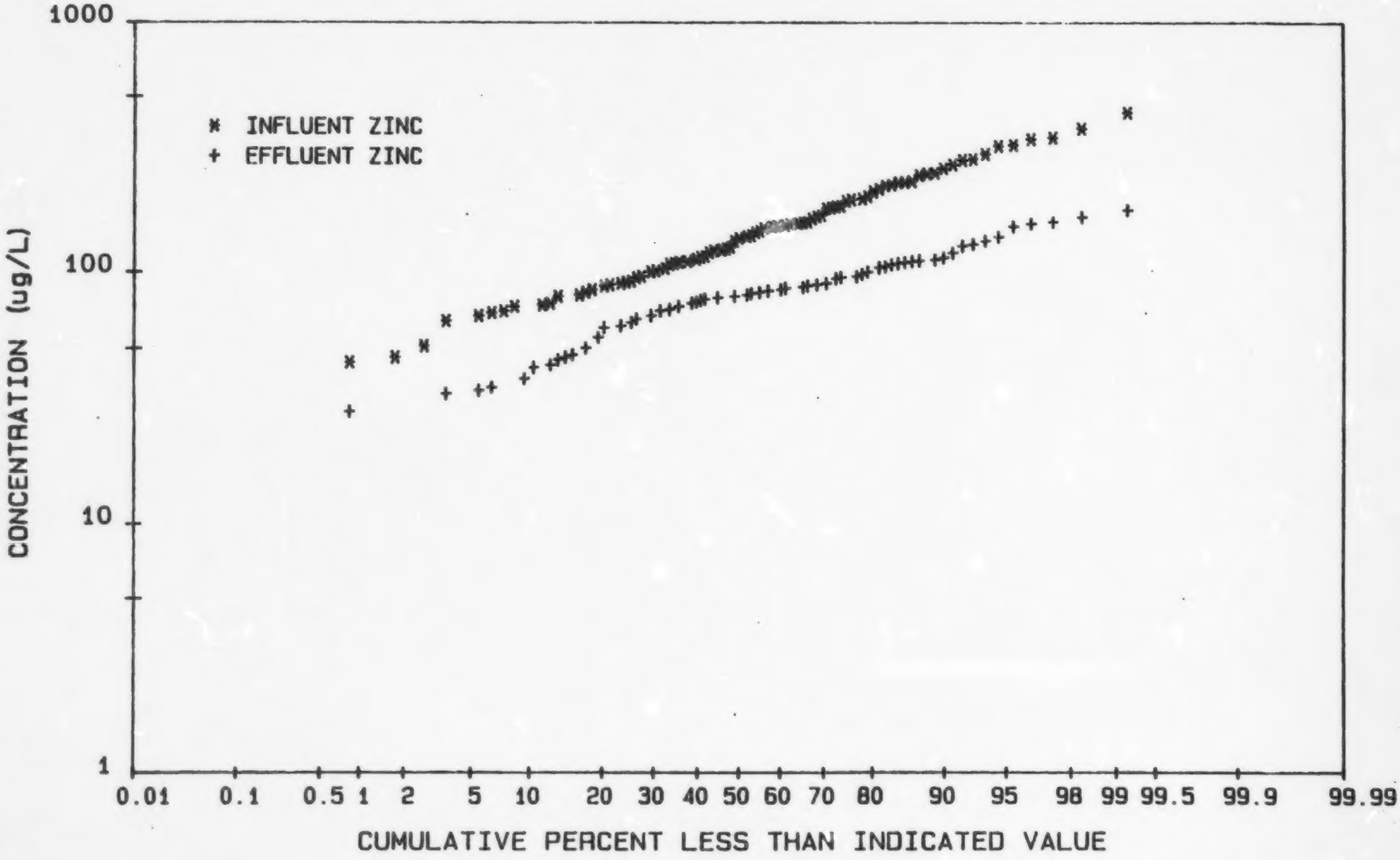


FIGURE 20 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT ZINC CONCENTRATION AT WATERLOO STP

Table 18
METAL CONTAMINANT DATA FOR WATERLOO STP

	Influent**					Effluent**				
Parameter*	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Cadmium	4.4	4.5	1.1	24.4	6.0	4.1	4.3	1.9	44.2	6.
Chromium	46.7	54.2	36.1	77.3	123.	27.3	29.8	14.8	49.7	64.
Copper	110.	122.	57.0	46.7	253.	13.5	14.3	4.2	29.4	21.
Nickel	26.0	27.3	10.2	37.3	44.	23.8	24.7	9.0	36.4	34.
Lead	13.6	20.4	20.2	99.0	65.	5.7	6.7	7.5	110.	15.
Zinc	135.	152.	78.3	51.5	321.	74.9	81.4	31.3	38.5	152.

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*All concentrations reported in μg/L. RSD reported in %.

**Based on 99 samples.

Many of the probability distributions for metals and organics (see Section 3.2.3) suggest that significantly fewer than 99 data points were collected in the influents and effluents at the Waterloo STP and the other two plants (Sections 4 and 5). This apparent anomaly relates to the convention of assigning probabilities to every discrete result instead of every result. For example, the probability distribution for cadmium (Figure 15) shows that only six different concentration values were found in the 99 influent samples and the 99 effluent samples analyzed.

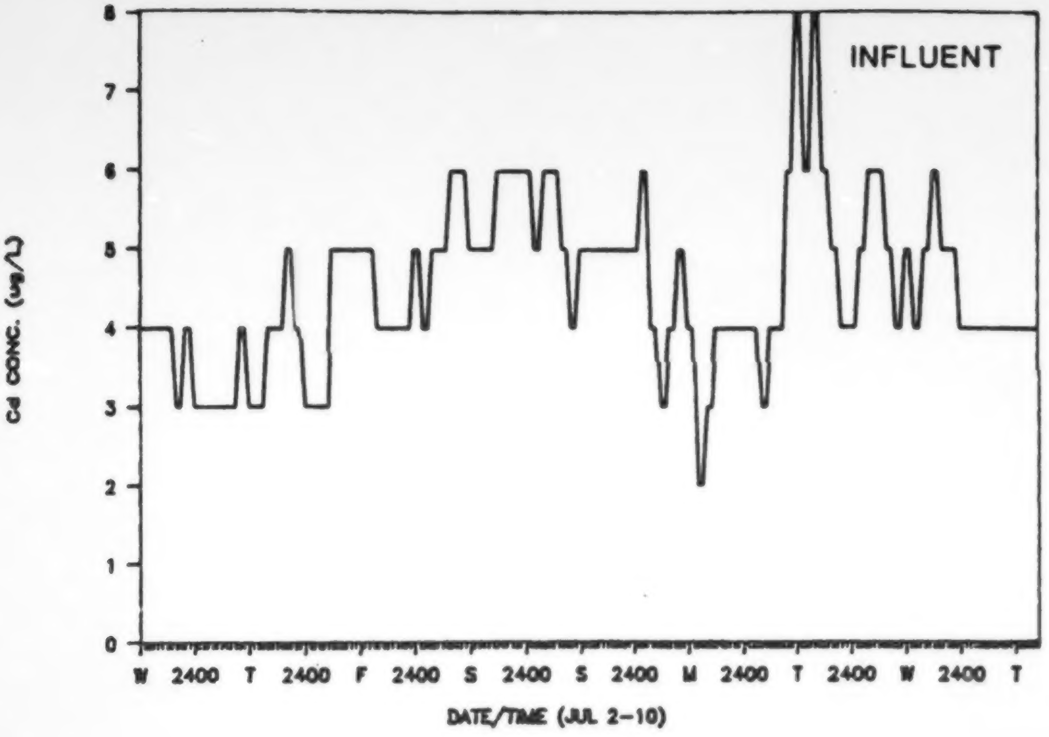
Chronological plots of influent and effluent metal concentrations, as shown in Figure 21 to 26, illustrate markedly different behaviour for the individual metals. Cadmium concentrations (Figure 21) were consistently near the detection limit in influents and effluents and the resolution of the analytical method at these concentrations was ±1.0 μg/L. Therefore, no significant pattern was apparent.

Chromium concentrations (Figure 22) showed a slight but significant diurnal trend in the influent based on the autocorrelation function of the data. A major perturbation was apparent near the start of the sampling period. There was no significant diurnal trend in the effluent chromium concentrations but two major excursions in the effluent were apparent. However, the large influent concentration spike noted on July 2 did not produce a significant effluent response.

Influent copper concentrations (Figure 23) showed a definite diurnal trend with lower concentrations on weekends than on weekdays. Effluent copper concentrations were more random in nature with no apparent diurnal trend.

Analysis of the influent nickel sequence (Figure 24) suggest a statistically significant diurnal pattern which is particularly apparent on weekdays. The effluent sequence shows two large pertubations around the generally stable baseline concentration of about 20 μg/L with no significant diurnal variation.

Lead concentrations in the Waterloo STP influent (Figure 25) showed a high degree of variability, but no significant diurnal pattern. Lead concentrations were at or below the method detection limit (5 μg/L) in more than 85 percent of



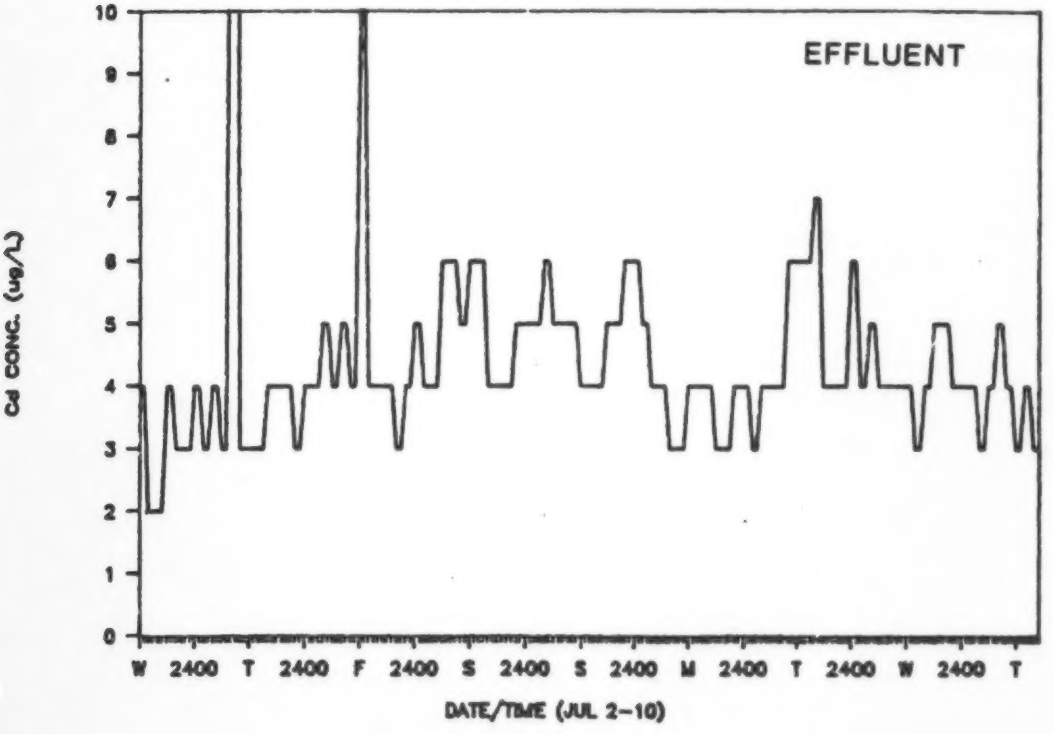


FIGURE 21: CHRONOLOGY OF INFLUENT AND EFFLUENT Cd AT WATERLOO WPCP

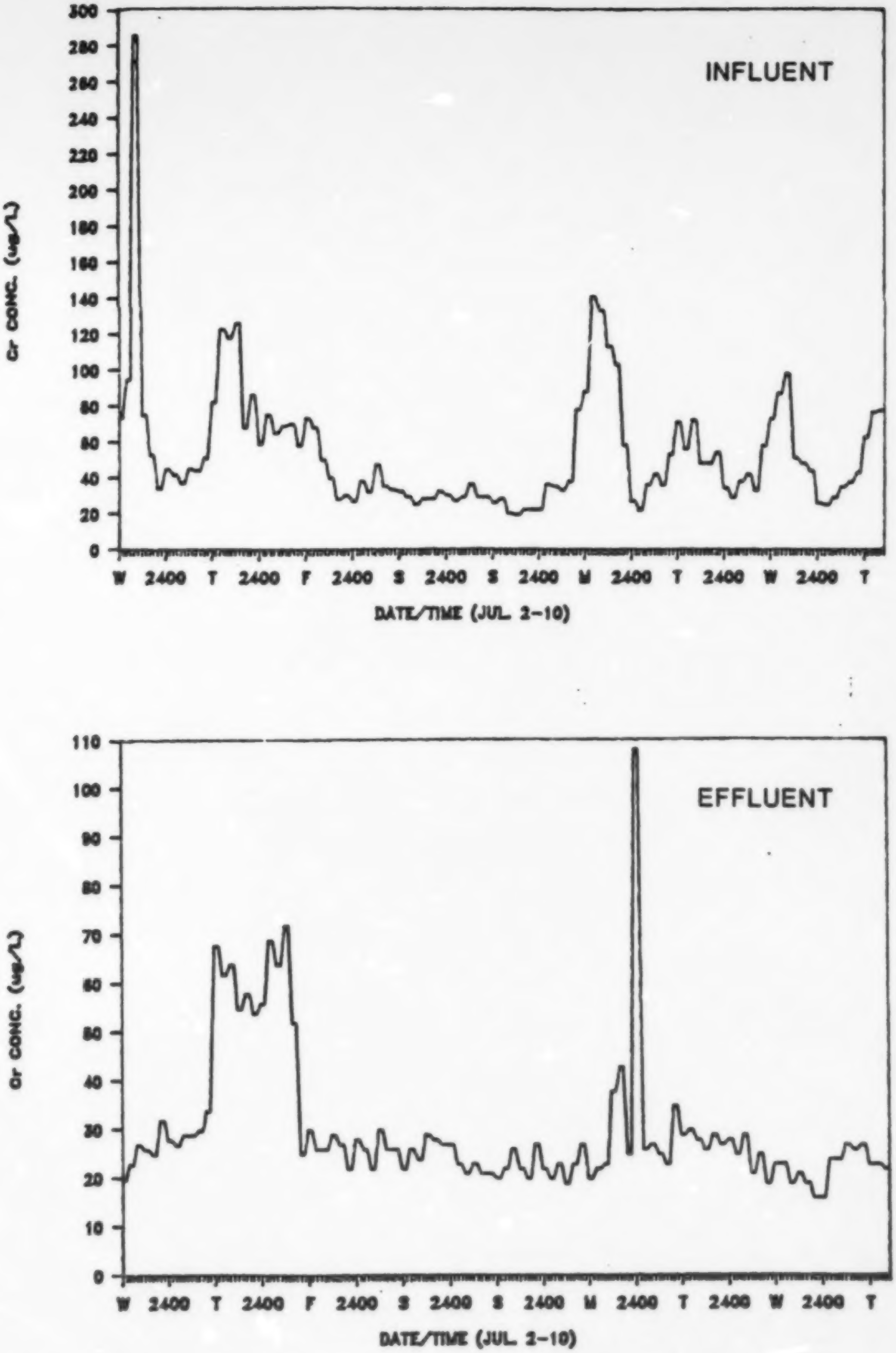


FIGURE 22: CHRONOLOGY OF INFLUENT AND EFFLUENT Cr AT WATERLOO WPCP

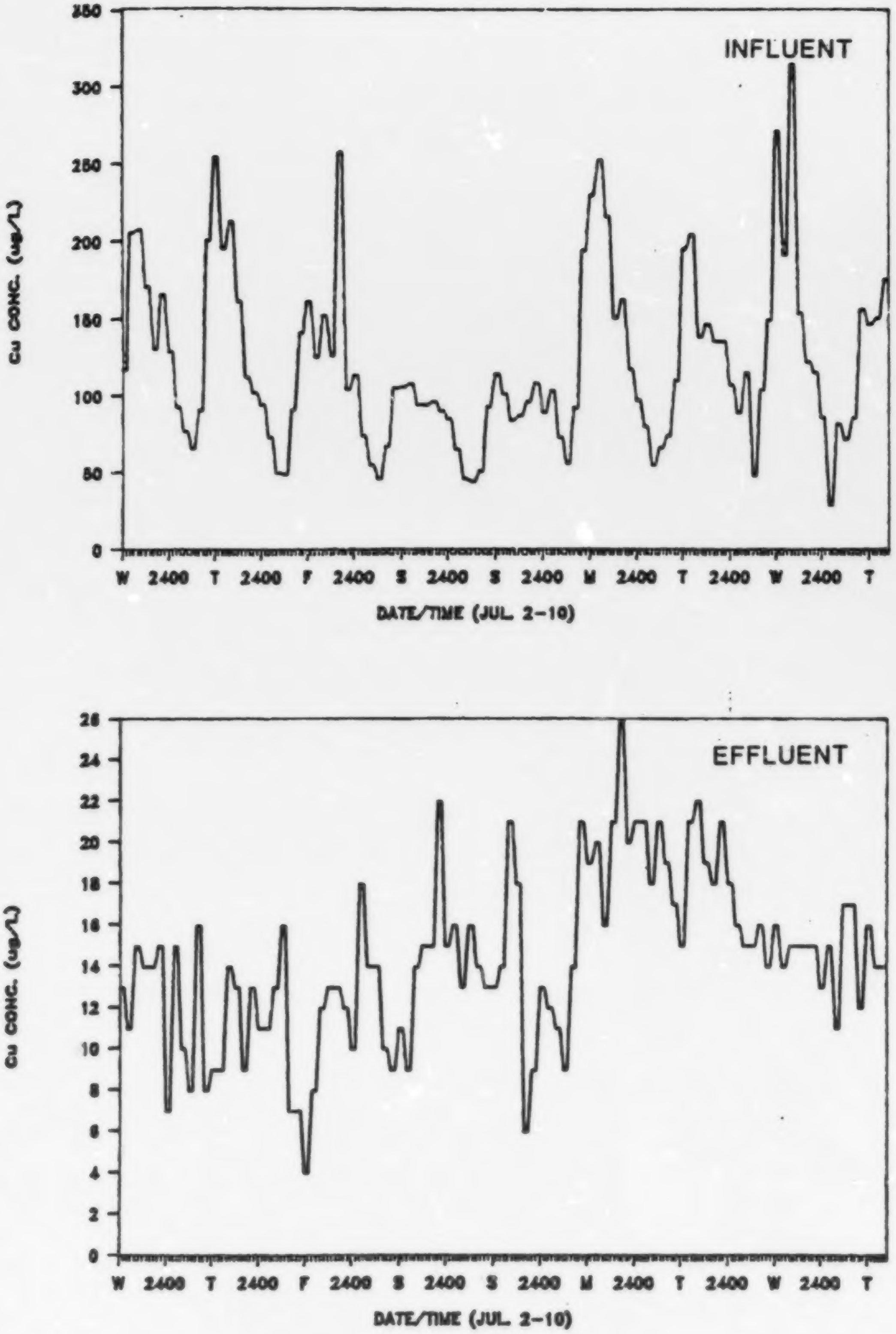


FIGURE 23: CHRONOLOGY OF INFLUENT AND EFFLUENT Cu AT WATERLOO WPCP

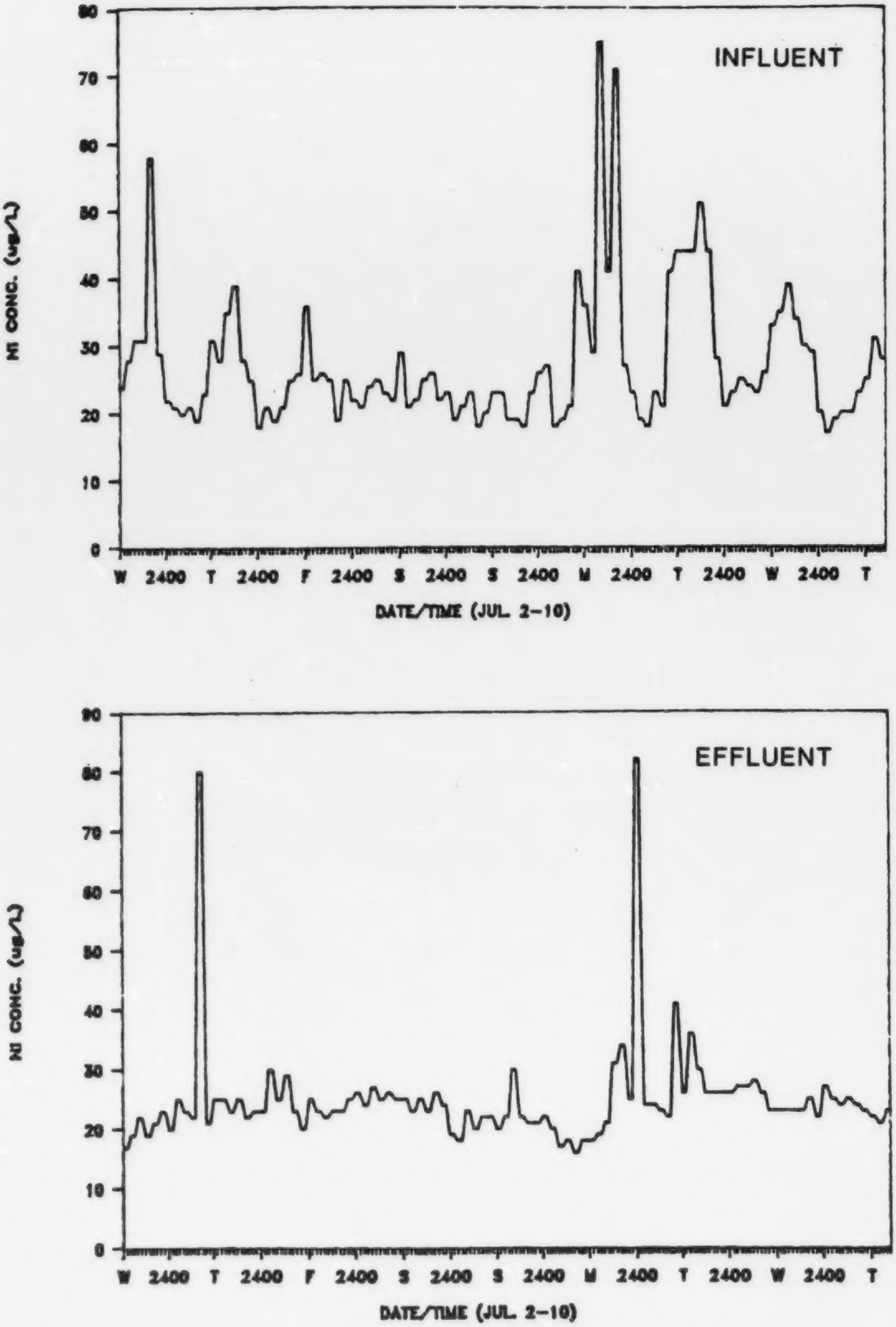
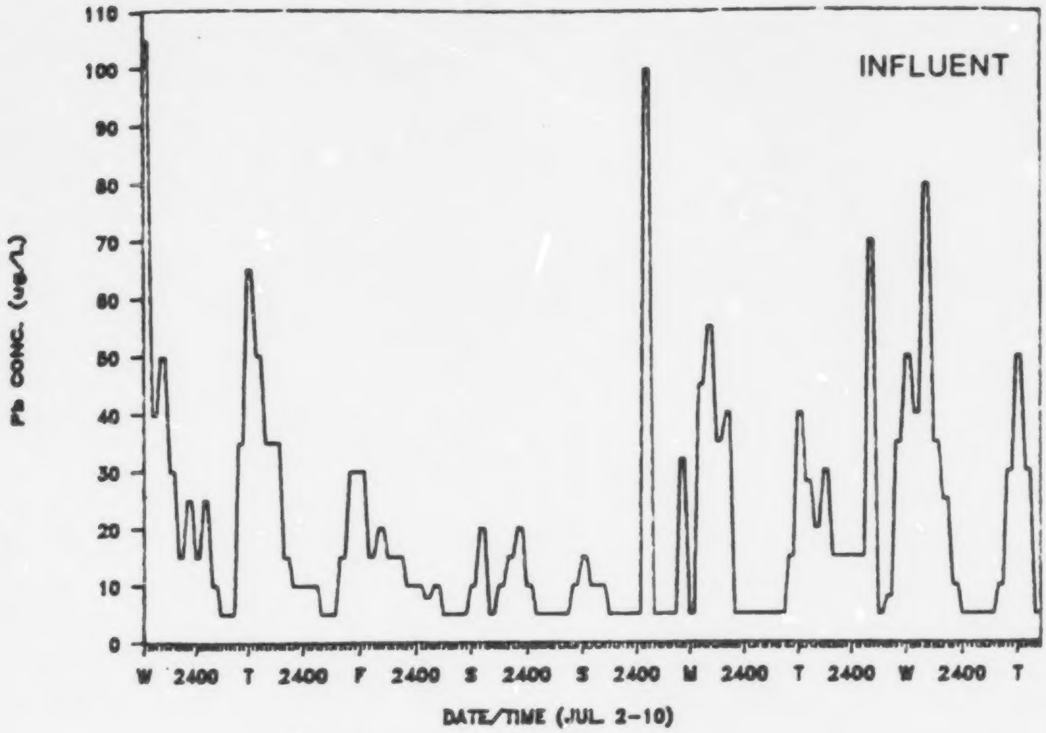


FIGURE 24: CHRONOLOGY OF INFLUENT AND EFFLUENT Ni AT WATERLOO WPCP



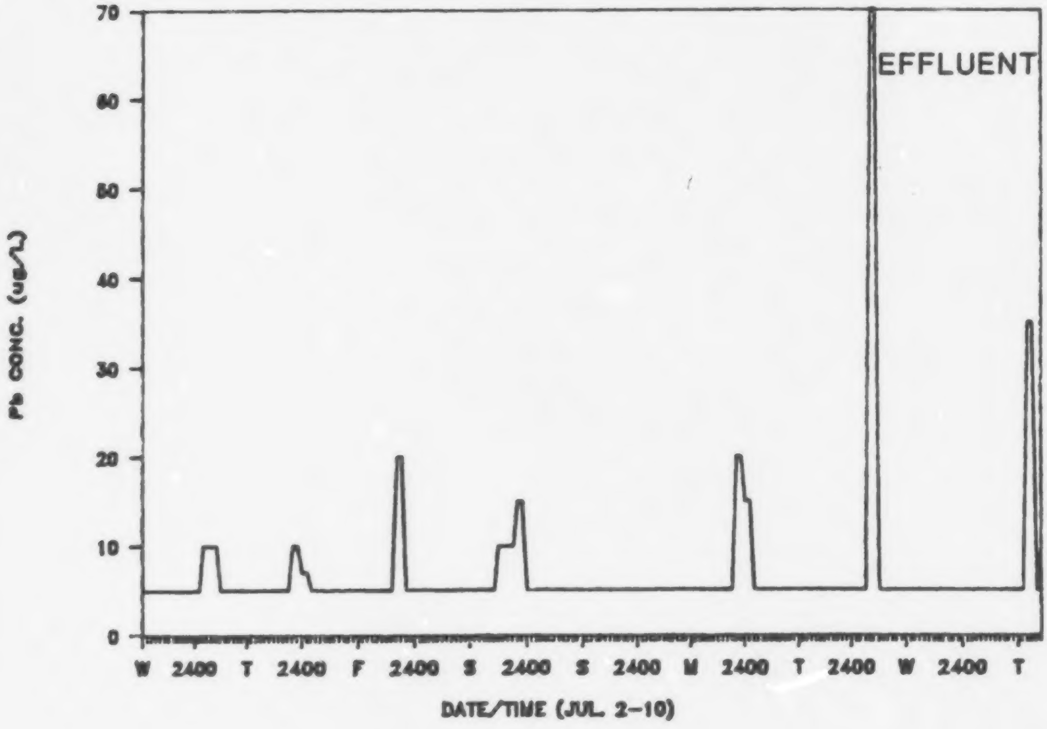


FIGURE 25: CHRONOLOGY OF INFLUENT AND EFFLUENT Pb AT WATERLOO WPCP

the effluent samples. However, almost daily effluent concentration spikes were noted. These effluent spikes did not correlate significantly with influent perturbations.

Zinc concentration in the raw sewage (Figure 26) also showed a high degree of variability with a significant diurnal trend. This diurnal trend was not apparent in the effluent concentration however.

Average removal efficiencies for the metal species are summarized in Table 19. Calculated cadmium removal efficiency was relatively low because influent and effluent concentrations were near the method detection limit. Calculated lead removal was low, although the majority of effluent samples contained concentrations below the detection limit. This anomaly relates to the convention of assigning a concentration value equal to half the detection limit to samples in which the contaminant was not detected. The other four metals followed a removal pattern similar to that reported in the literature(4), with nickel being the most poorly removed with an efficiency of only 10 percent and copper being the most efficiently removed at an efficiency of near 90 percent.

Table 19
REMOVAL OF HEAVY METALS IN WATERLOO STP

Metal	Removal (Percent) Based on Arithmetic Mean	Removal (Percent) Based on Geometric Mean
Cadmium	4.4	6.8
Chromium	45.0	41.5
Copper	88.3	87.7
Nickel	9.5	8.5
Lead	67.2	58.1
Zinc	46.4	44.5

3.2.3 Trace Organics

3.2.3.1 Phenolics

The probability distributions of influent and effluent total phenolics concentrations are presented in Figure 27. The geometric mean influent concentration was 16.2 µg/L, (arithmetic mean 20.7 µg/L, RSD = 59.9 percent) compared to a

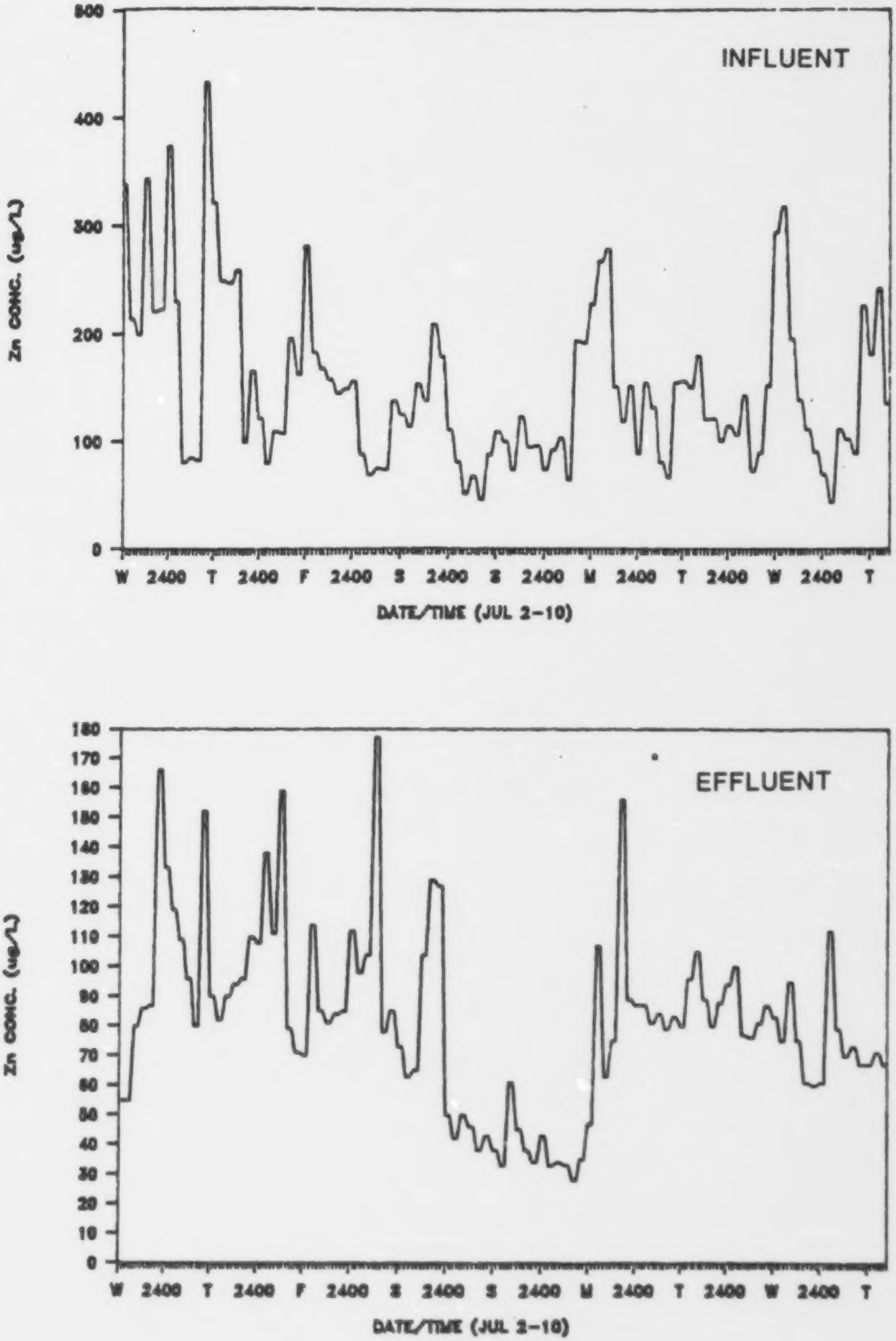


FIGURE 26: CHRONOLOGY OF INFLUENT AND EFFLUENT Zn AT WATERLOO WPCP

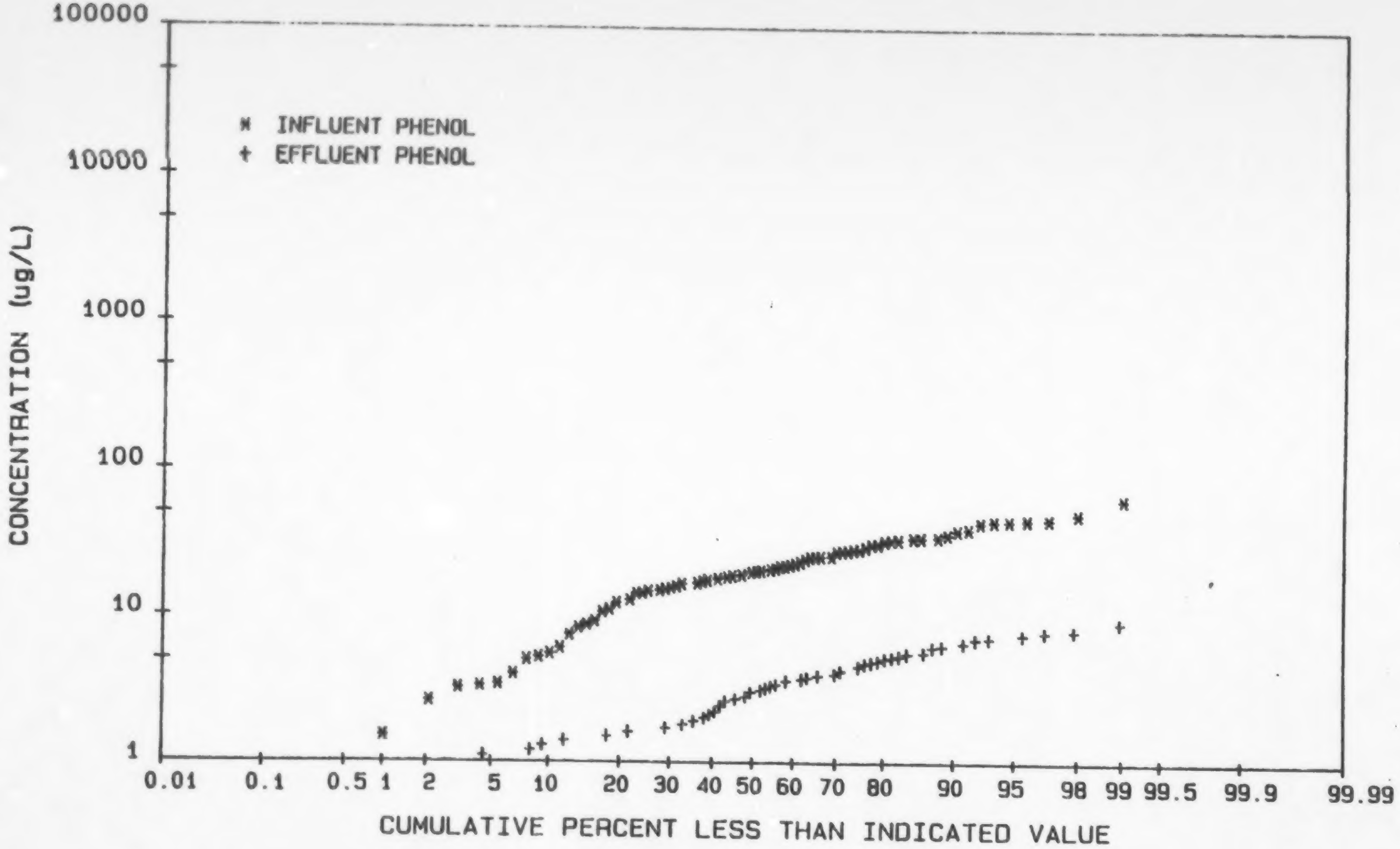


FIGURE 27 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT PHENOL CONCENTRATION AT WATERLOO STP

geometric mean effluent concentration of 2.7 μg/L (arithmetic mean 3.3 μg/L, RSD = 60.6 percent). Average removal, based on the geometric mean was 84 percent.

The chronological data trend is illustrated in Figure 28. There was a slight, but statistically significant, diurnal variation in the raw wastewater sequence based on the autocorrelation function. No such diurnal trend was apparent in the effluent sequence.

3.2.3.2 Volatile Organics

Table 20 summarizes the frequency of detection (FOD) of selected chlorinated and non-chlorinated organics in raw sewages and effluents from the Waterloo STP. Of the twenty-one volatile organic compounds included in the GC scan, ten were present in the influent wastewater at a concentration in excess of the method detection limit (MDL) more than 50 percent of the time. Of these ten, five were aromatic hydrocarbons (benzene, toluene, xylene isomers and ethylbenzene). The remainder were chlorinated compounds (dichloromethane, chloroform, 1,1,1-trichloroethane, trichloroethylene and 1,4-dichlorobenzene). Dichloromethane was identified in all influent and effluent samples (FOD = 100%) and in travel blanks. Its consistent presence is considered to represent laboratory contamination. There were no other volatile contaminants identified at an FOD greater than 50 percent in effluent samples. Three chlorinated compounds (chloroform, 1,1,1-trichloroethane and 1,4-dichlorobenzene) were present more than 20 percent of the time. All of the aromatic hydrocarbons which had been frequently identified in the raw wastewater were quantified in less than 10 percent of the effluent samples.

Probability distributions for volatile organics commonly found in the Waterloo STP influents and effluents are presented in Figure 29 (benzene), Figure 30 (toluene), Figure 31 (p & m-xylene), Figure 32 (chloroform), Figure 33 (1,4-dichlorobenzene), Figure 34 (1,1,1-trichloroethane) and Figure 35 (trichloroethylene). Statistics characterizing these distributions are summarized in Table 21. In these calculations, concentrations reported as 'trace' were assigned a value equal to the MDL and concentrations reported as 'not detected' were assigned a value equal to MDL/2. Chronological plots for these compounds are shown in Figures 36 to 42. Because of the relatively low FOD in

Table 20
FREQUENCY OF DETECTION OF VOLATILE ORGANIC CONTAMINANTS AT WATERLOO STP

Compound	MDL µg/L	Frequency of Detection* (%) Influent	Effluent
Dichloromethane	1.0	100	100
Chloroform	1.0	88	30
1,2-dichloroethylene	1.0	0	0
1,1,1-trichloroethane	1.0	57	20
Benzene	0.5	94	1
Carbon tetrachloride	1.0	0	0
Bromodichloromethane	1.0	0	0
Trichloroethylene	1.0	65	3
1,1,2-trichloroethane	1.0	1	0
Toluene	0.5	92	4
Dibromochloromethane	1.0	0	0
Tetrachloroethylene	1.0	41	0
Chlorobenzene	0.5	3	0
Ethylbenzene	0.5	76	4
p & m-xylene	0.5	98	8
Bromoform	1.0	0	0
o-xylene	0.5	92	4
1,1,2,2-tetrachloroethane	1.0	2	0
1,3-dichlorobenzene	1.0	3	0
1,4-dichlorobenzene	1.0	55	22
1,2-dichlorobenzene	1.0	27	13

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* At concentrations above the MDL.

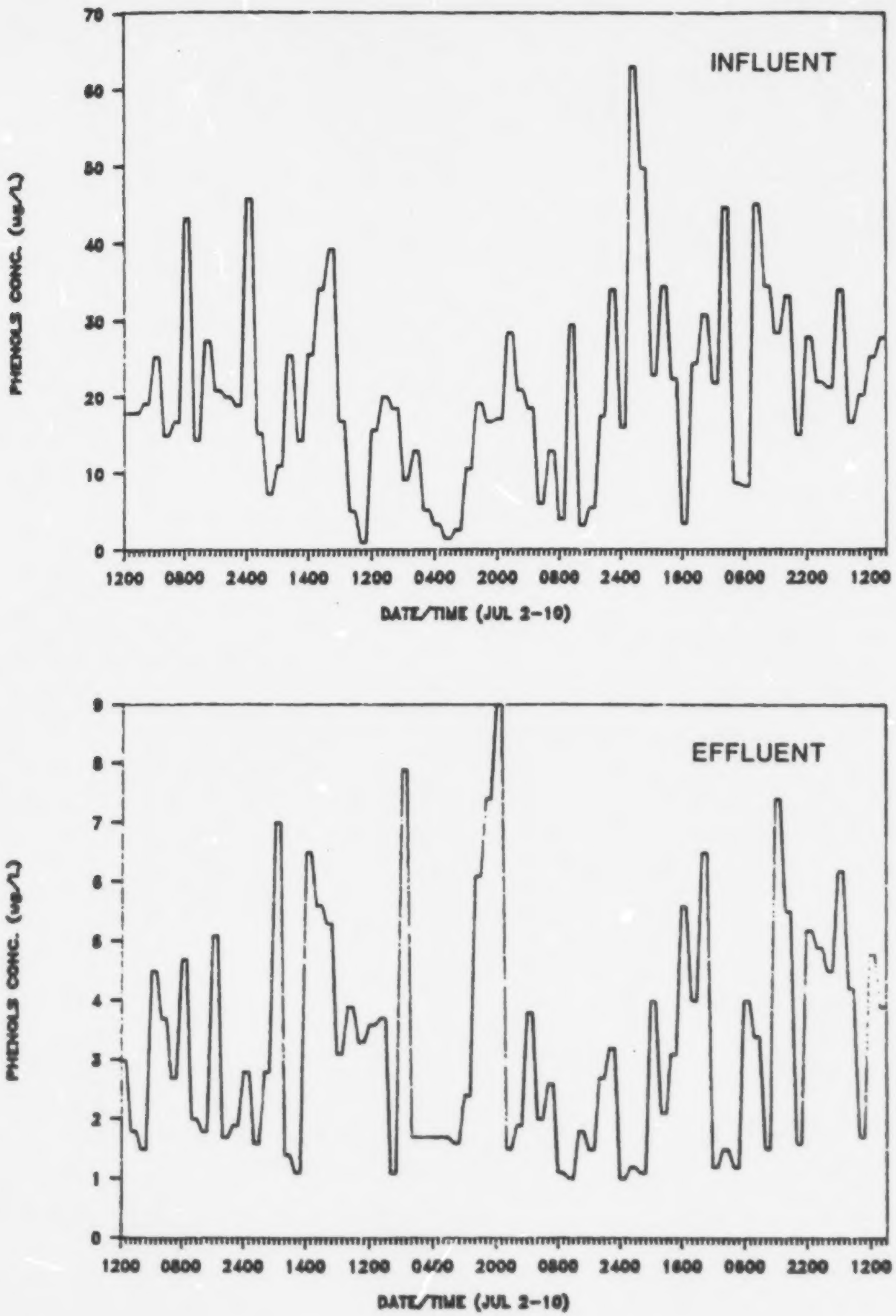

FIGURE 28: CHRONOLOGY OF INFLUENT AND EFFLUENT TOTAL PHENOLS AT WATERLOO WPCP

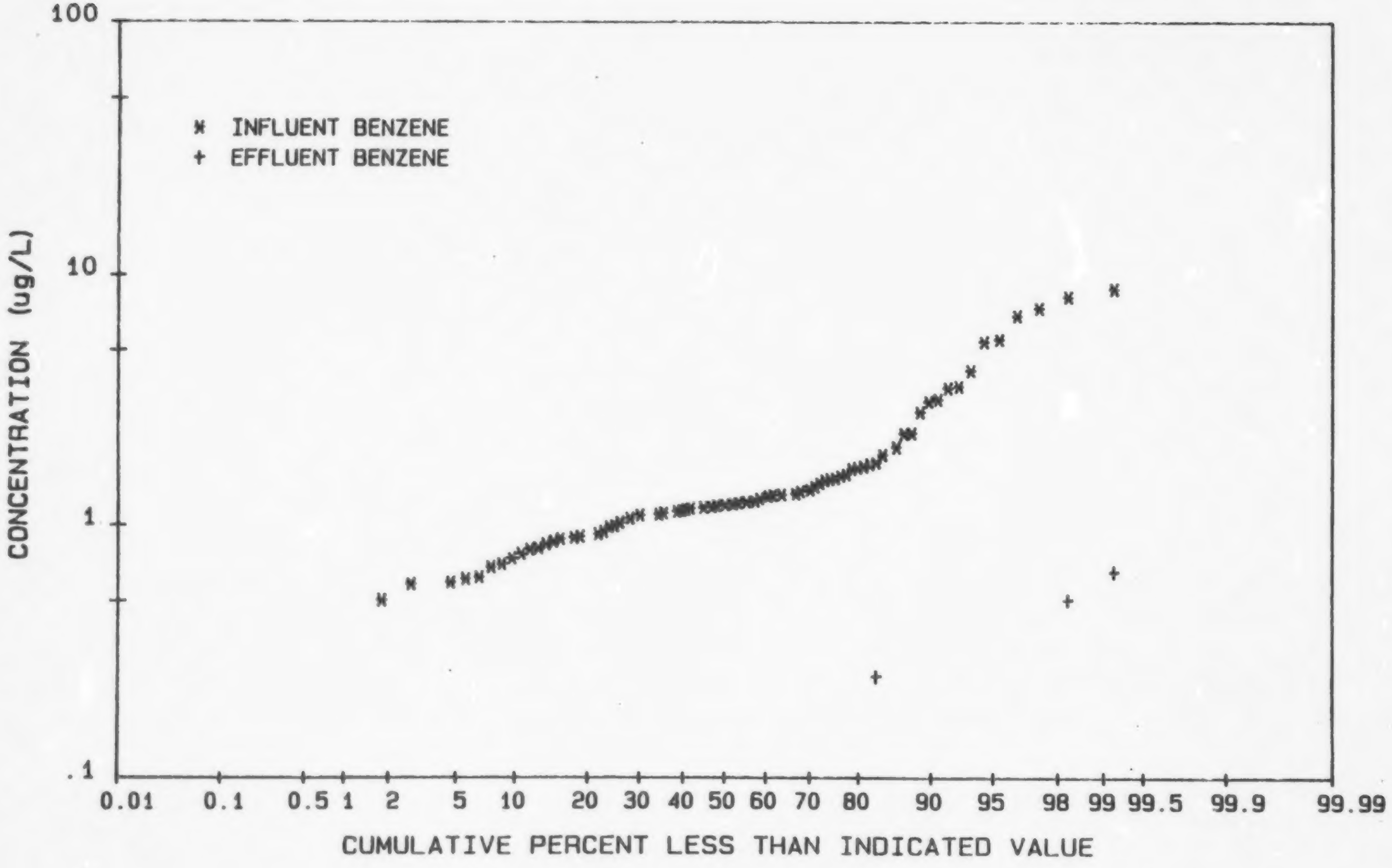

FIGURE 29 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT BENZENE CONCENTRATION AT WATERLOO STP

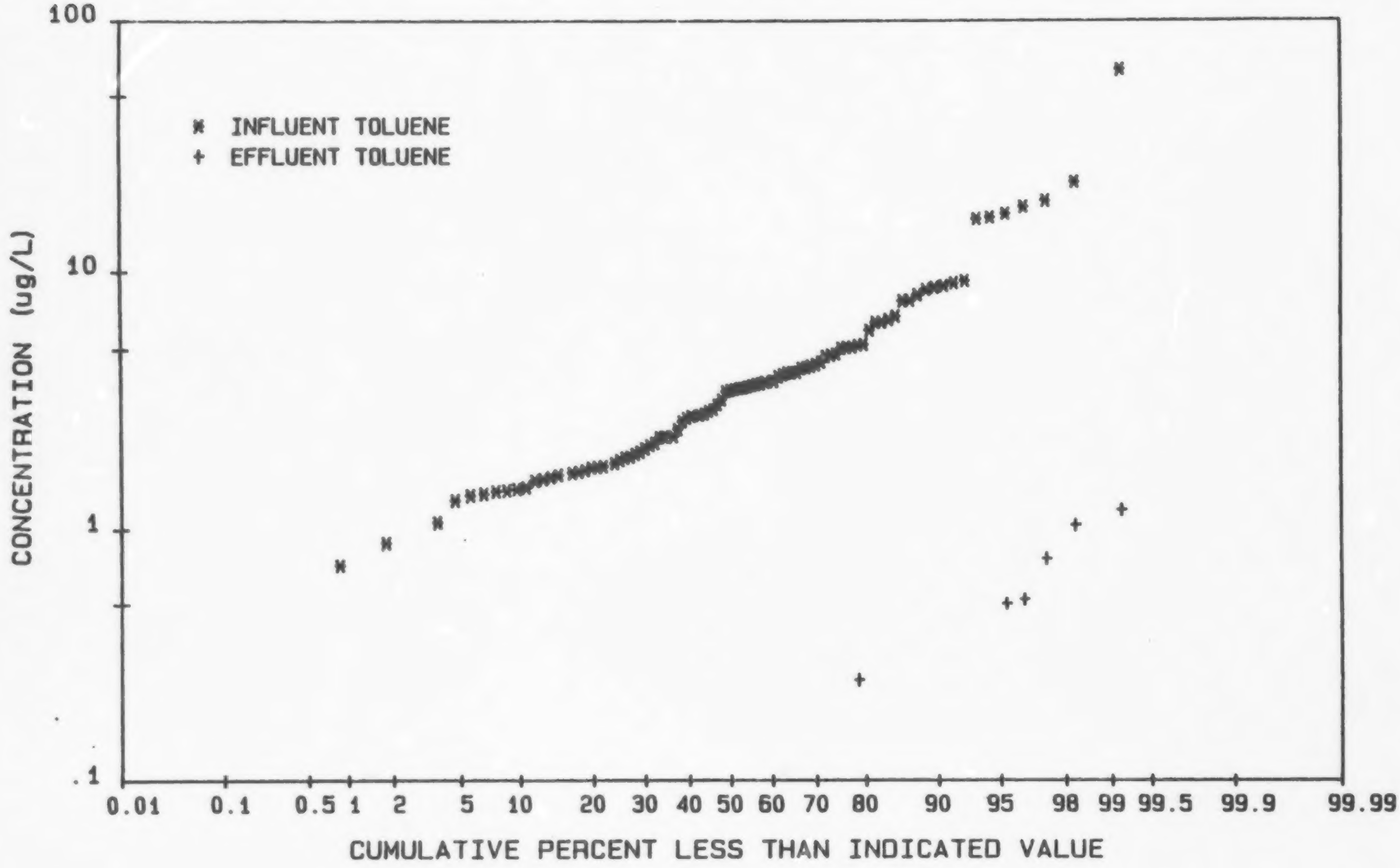

FIGURE 30 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOLUENE CONCENTRATION AT WATERLOO STP

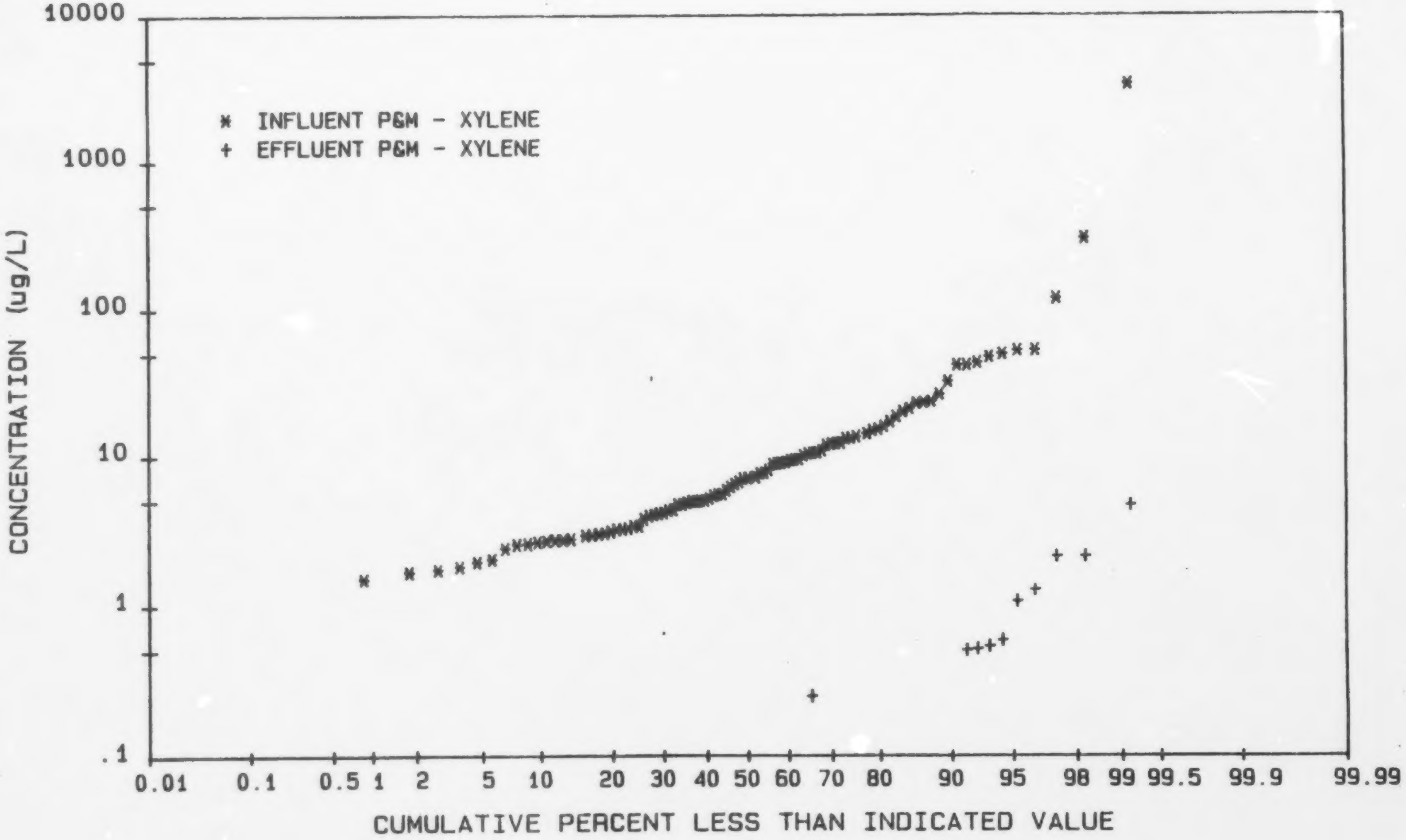

FIGURE 31 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT P&M - XYLENE CONCENTRATION AT WATERLOO STP

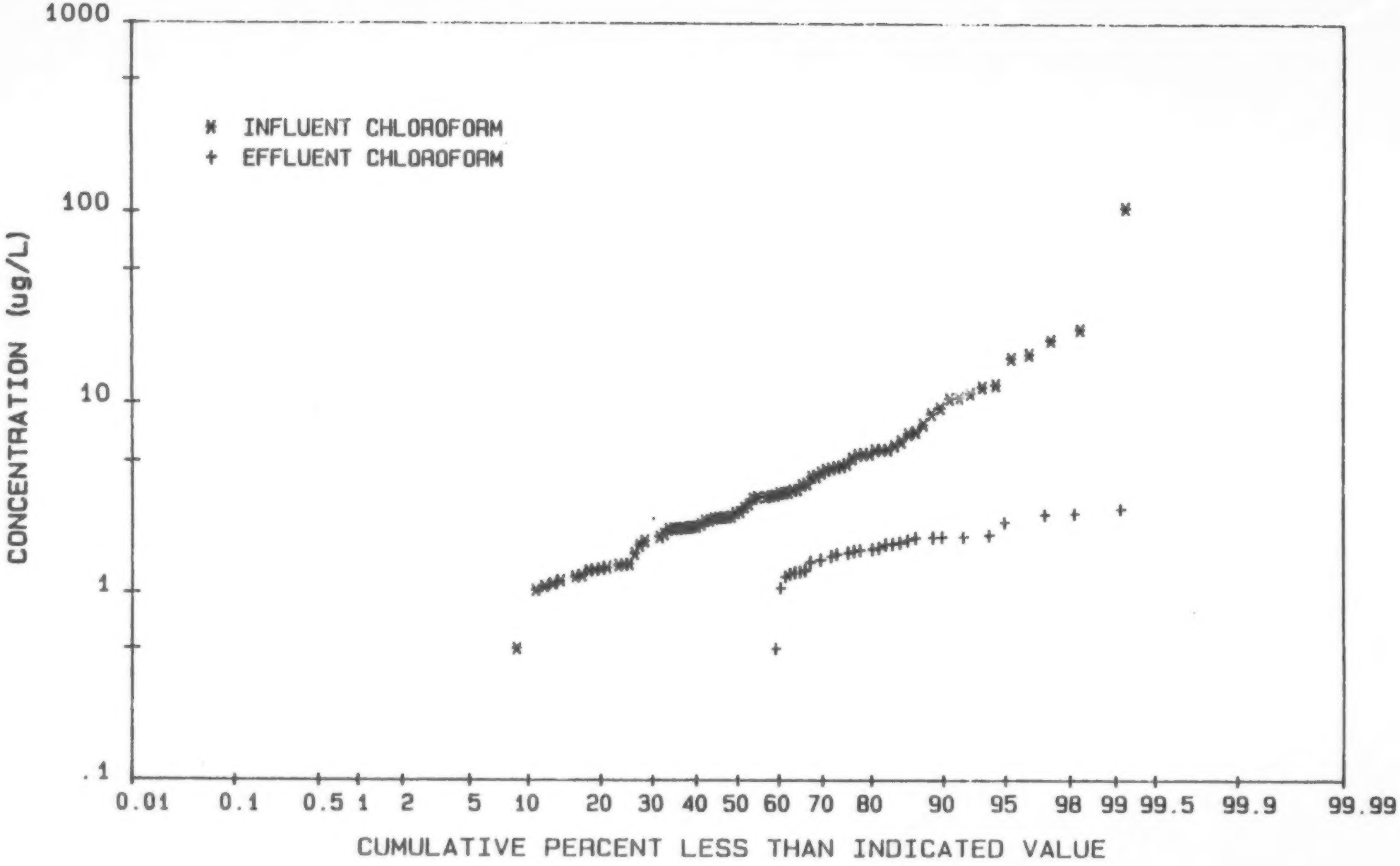

FIGURE 32 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHLOROFORM CONCENTRATION AT WATERLOO STP

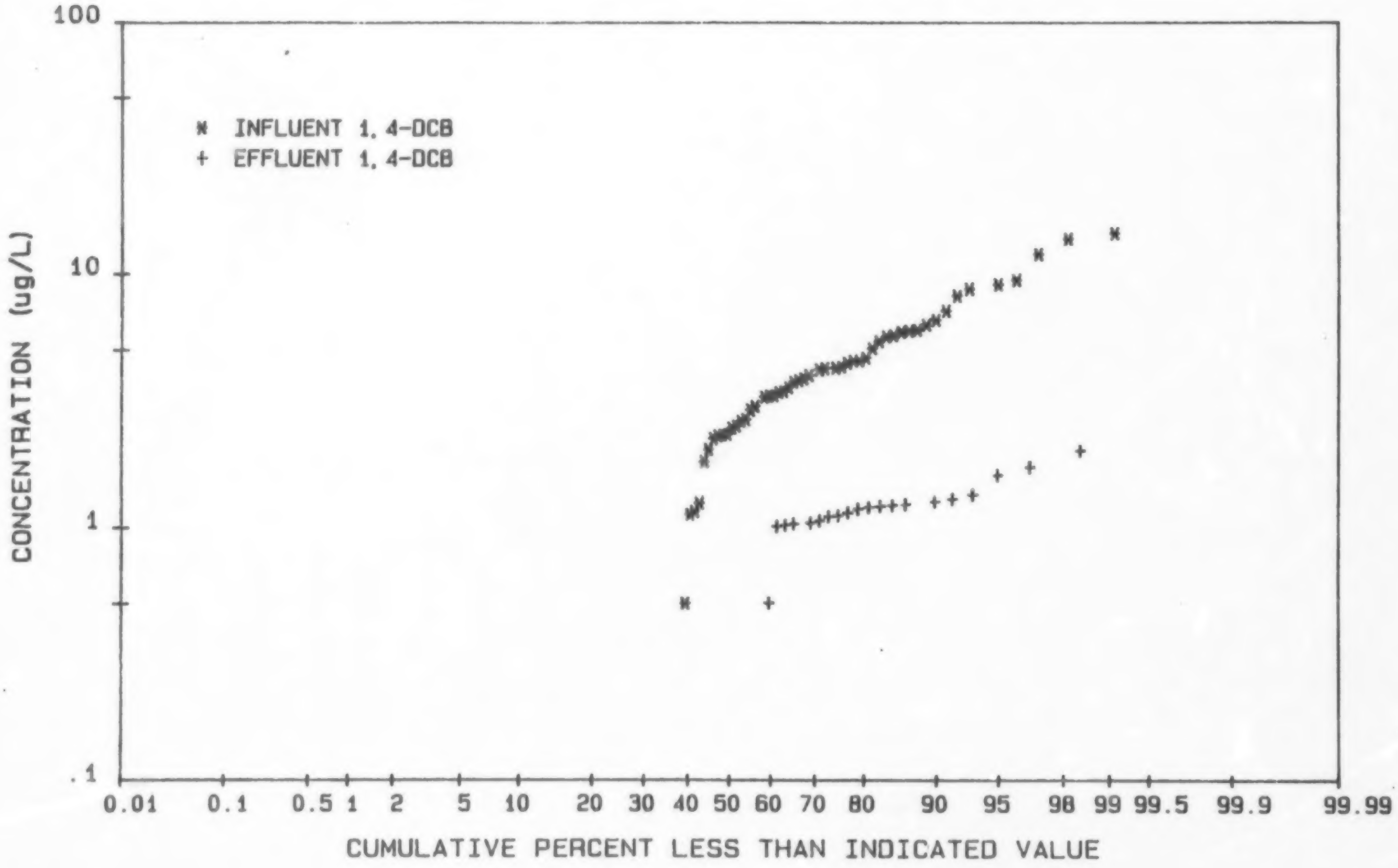

FIGURE 33 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT 1, 4-DICHLOROBENZENE CONCENTRATION AT WATERLOO STP

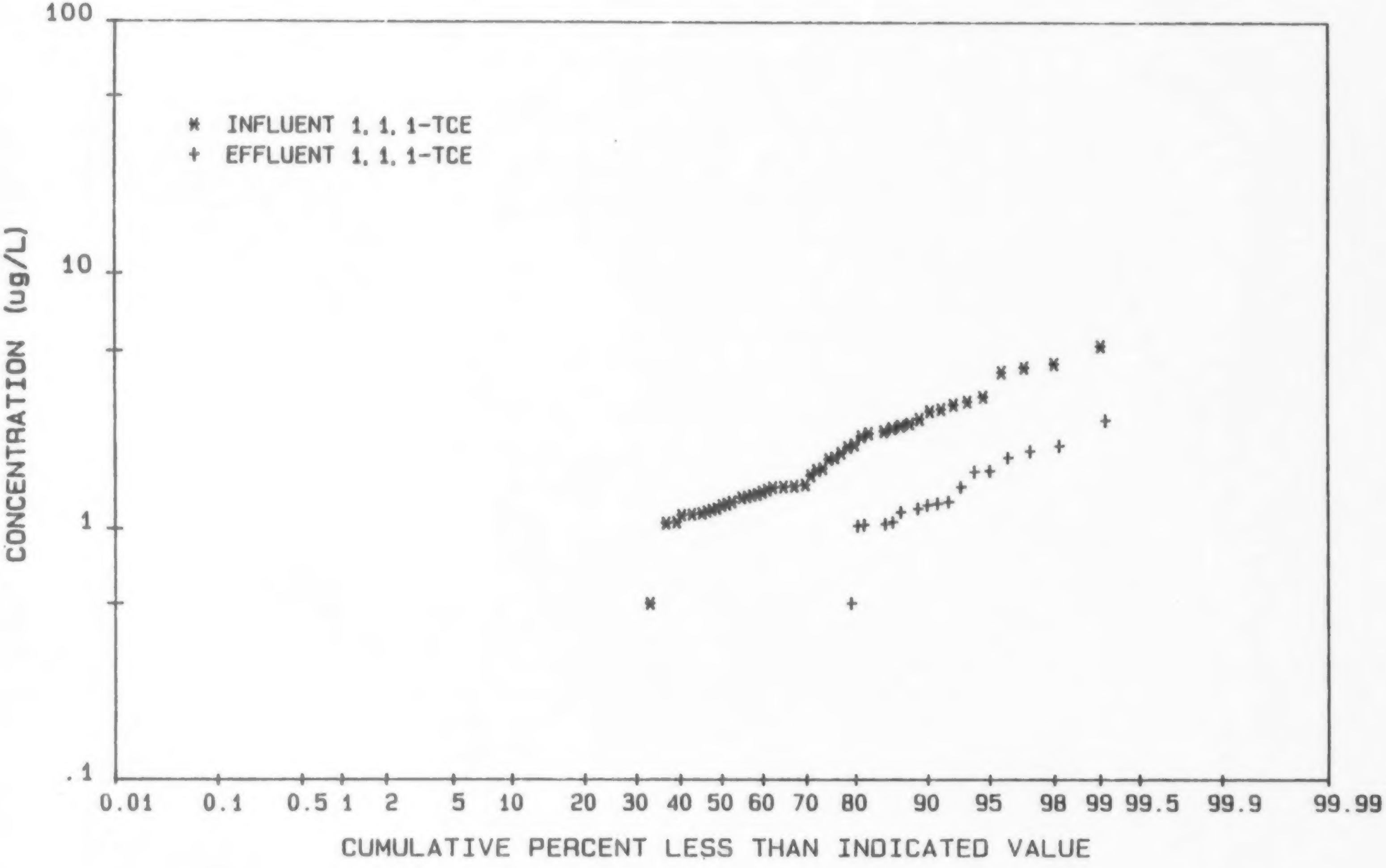

FIGURE 34 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT 1, 1, 1-TRICHLOROETHANE CONCENTRATION AT WATERLOO STP

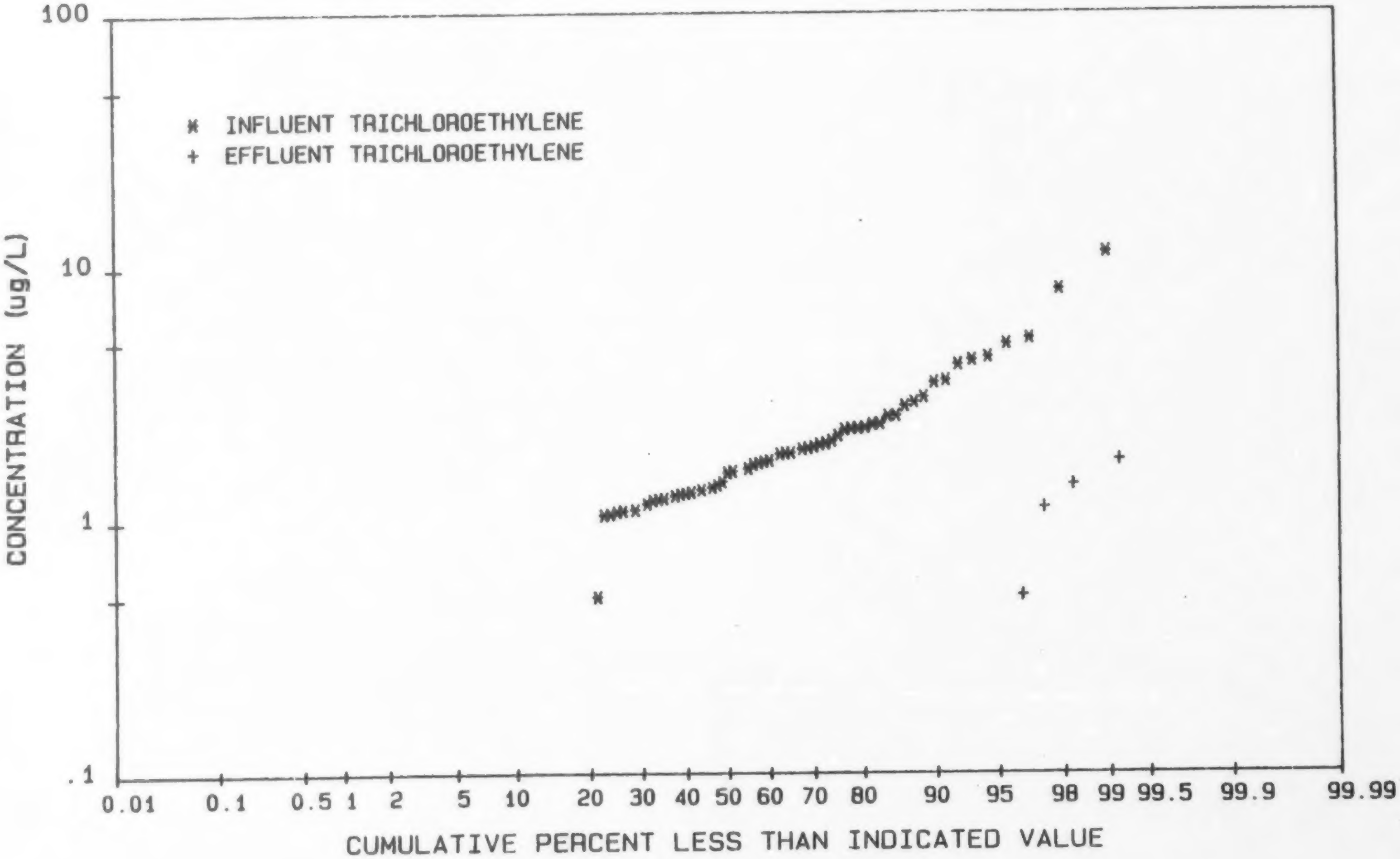

FIGURE 35 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE CONCENTRATION AT WATERLOO STP

Table 21
VOLATILE ORGANIC CONCENTRATION DATA FOR WATERLOO STP

Parameter*	Influent** Geo. Mean	Influent** Arith. Mean	Influent** Std.Dev.	Influent** RSD	Influent** 95th Percentile	Effluent** Geo. Mean	Effluent** Arith. Mean	Effluent** Std.Dev.	Effluent** RSD	Effluent** 95th Percentile
Benzene	1.4	1.7	1.6	94.1	5.5	0.3	0.3	0.01	3.3	0.5
Toluene	3.4	5.0	7.3	146.	17.0	0.3	0.3	0.2	66.7	0.5
p & m-xylene	8.3	50.4	345.	685.	52.8	0.3	0.4	0.3	75.0	1.1
Chloroform	2.8	5.2	11.2	220.	17.3	0.8	1.0	0.7	70.0	2.4
1,1,1-trichloroethane	1.1	1.4	1.0	71.4	3.3	0.6	0.7	0.4	57.1	1.7
1,4-dichlorobenzene	1.7	2.9	3.0	103.	9.1	0.8	0.9	0.3	33.3	1.3
Trichloroethylene	1.3	1.7	1.5	88.2	4.3	0.5	0.5	0.2	40.0	0.5

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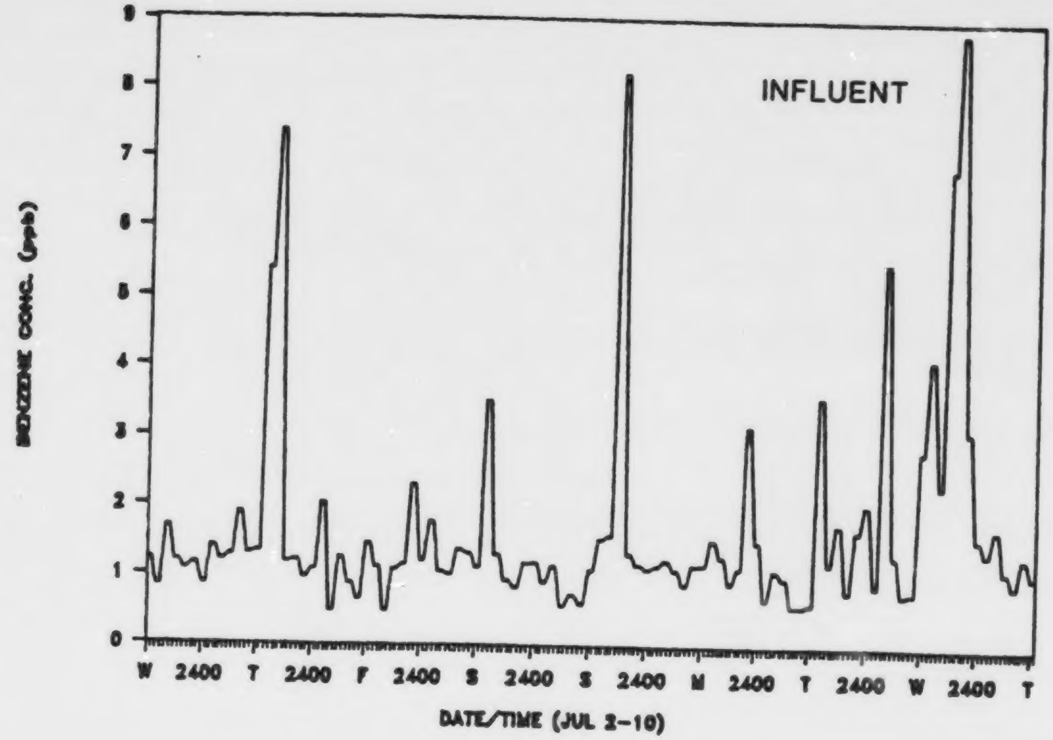
*All concentrations reported in µg/L. RSD reported in %.
**Based on 97 samples.



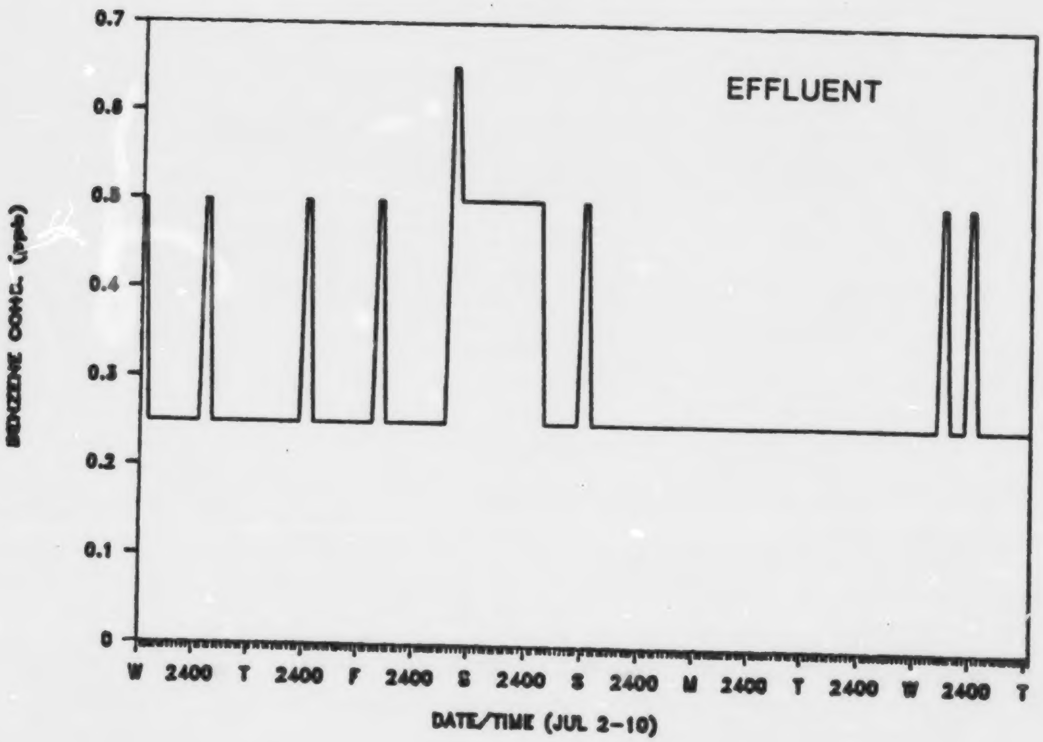
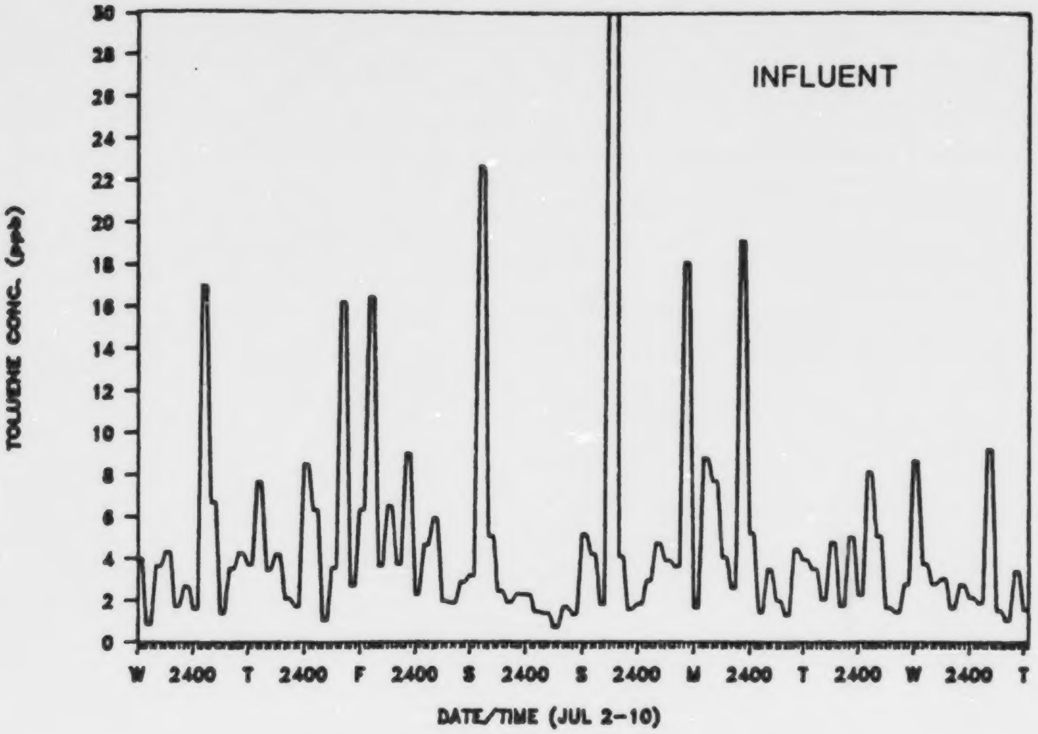


FIGURE 36: CHRONOLOGY OF INFLUENT AND EFFLUENT BENZENE AT WATERLOO WPCP



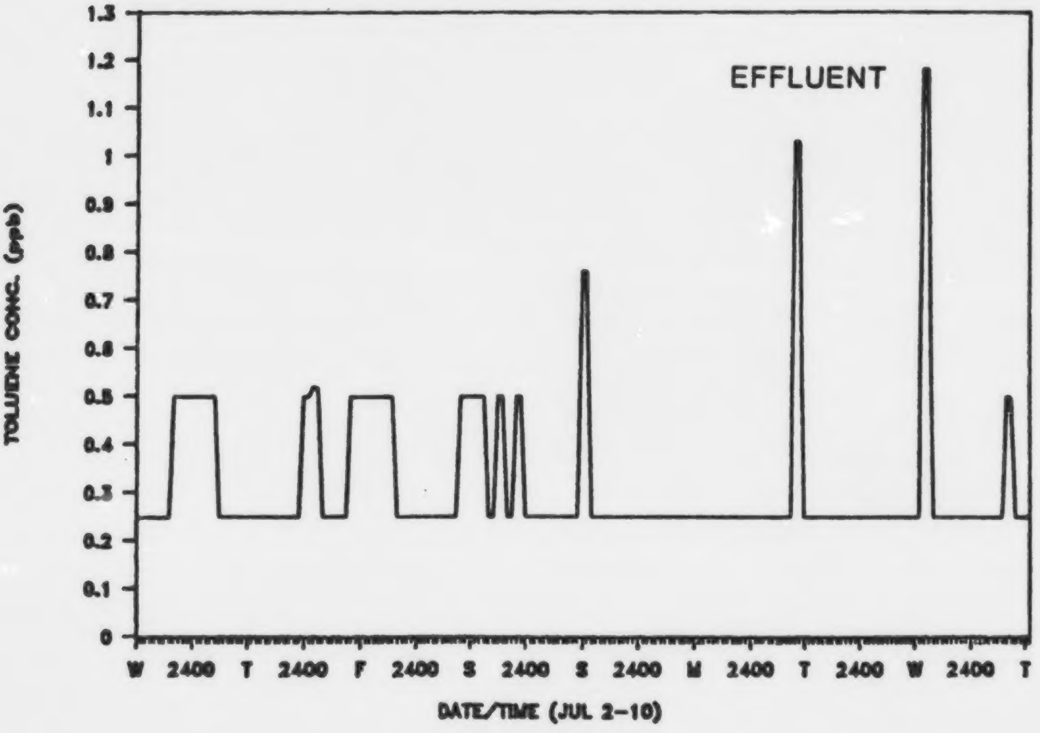


FIGURE 37: CHRONOLOGY OF INFLUENT AND EFFLUENT TOLUENE AT WATERLOO WPCP

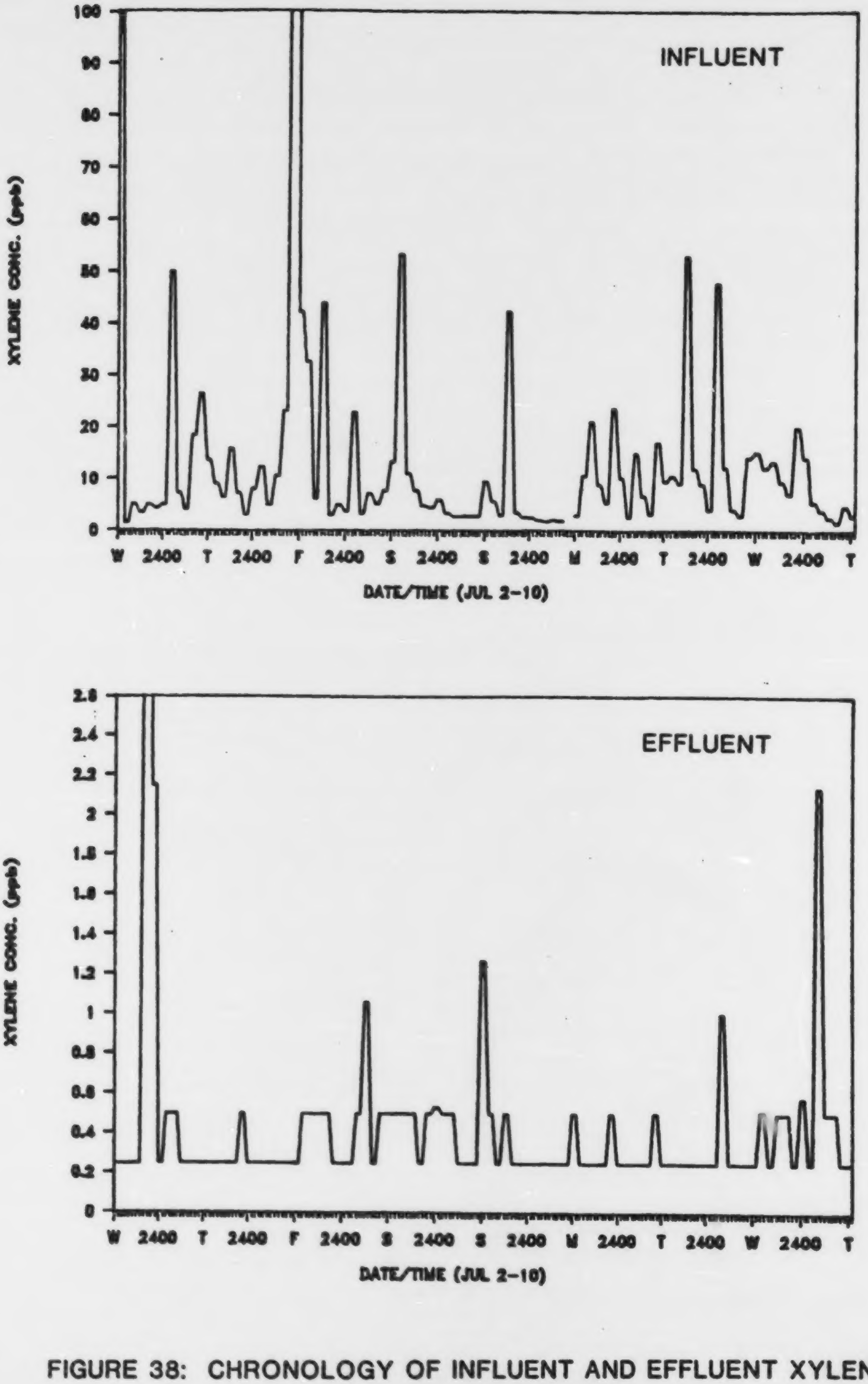


FIGURE 38: CHRONOLOGY OF INFLUENT AND EFFLUENT XYLENE AT WATERLOO WPCP

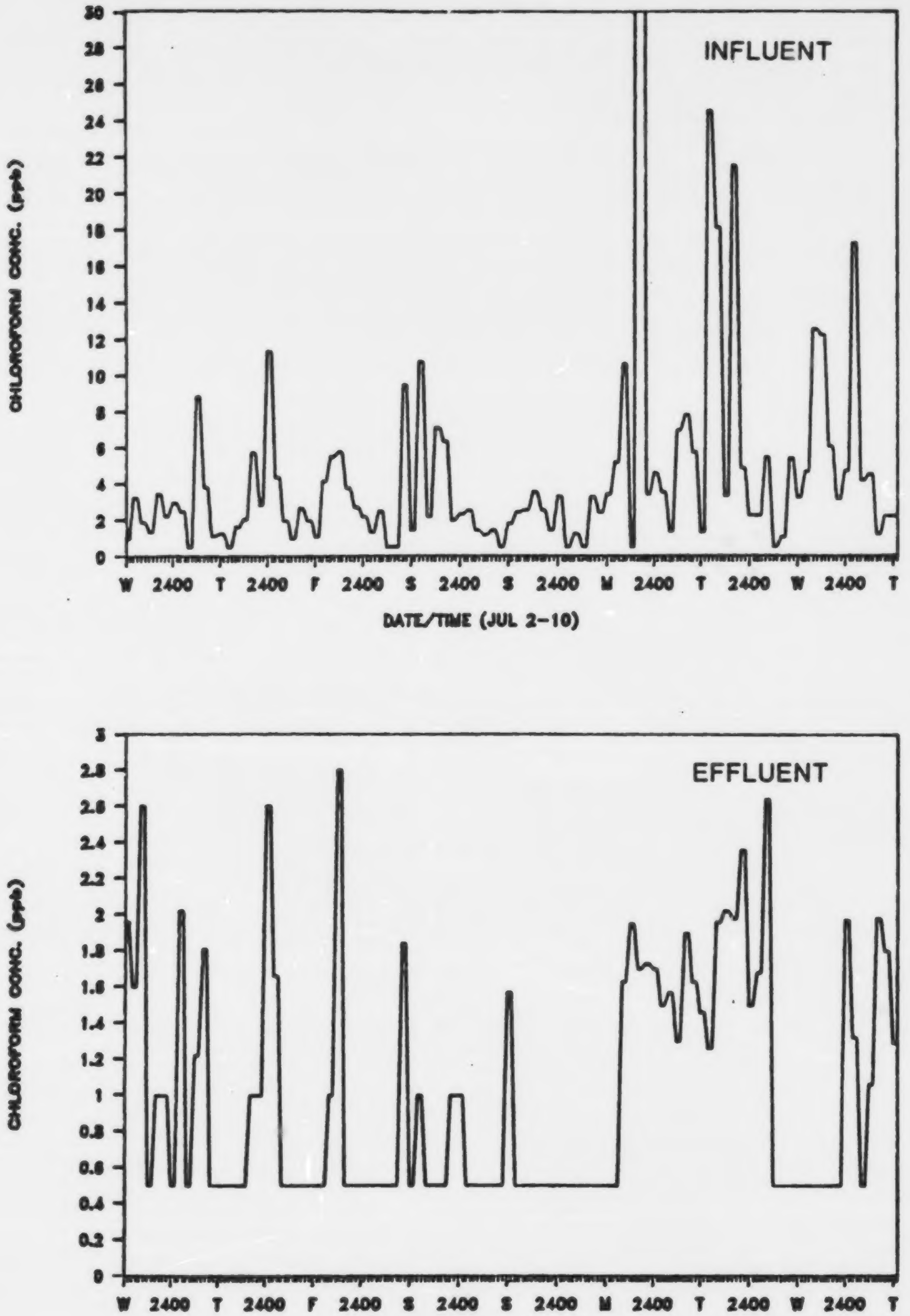


FIGURE 39: CHRONOLOGY OF INFLUENT AND EFFLUENT CHLOROFORM AT WATERLOO WPCP

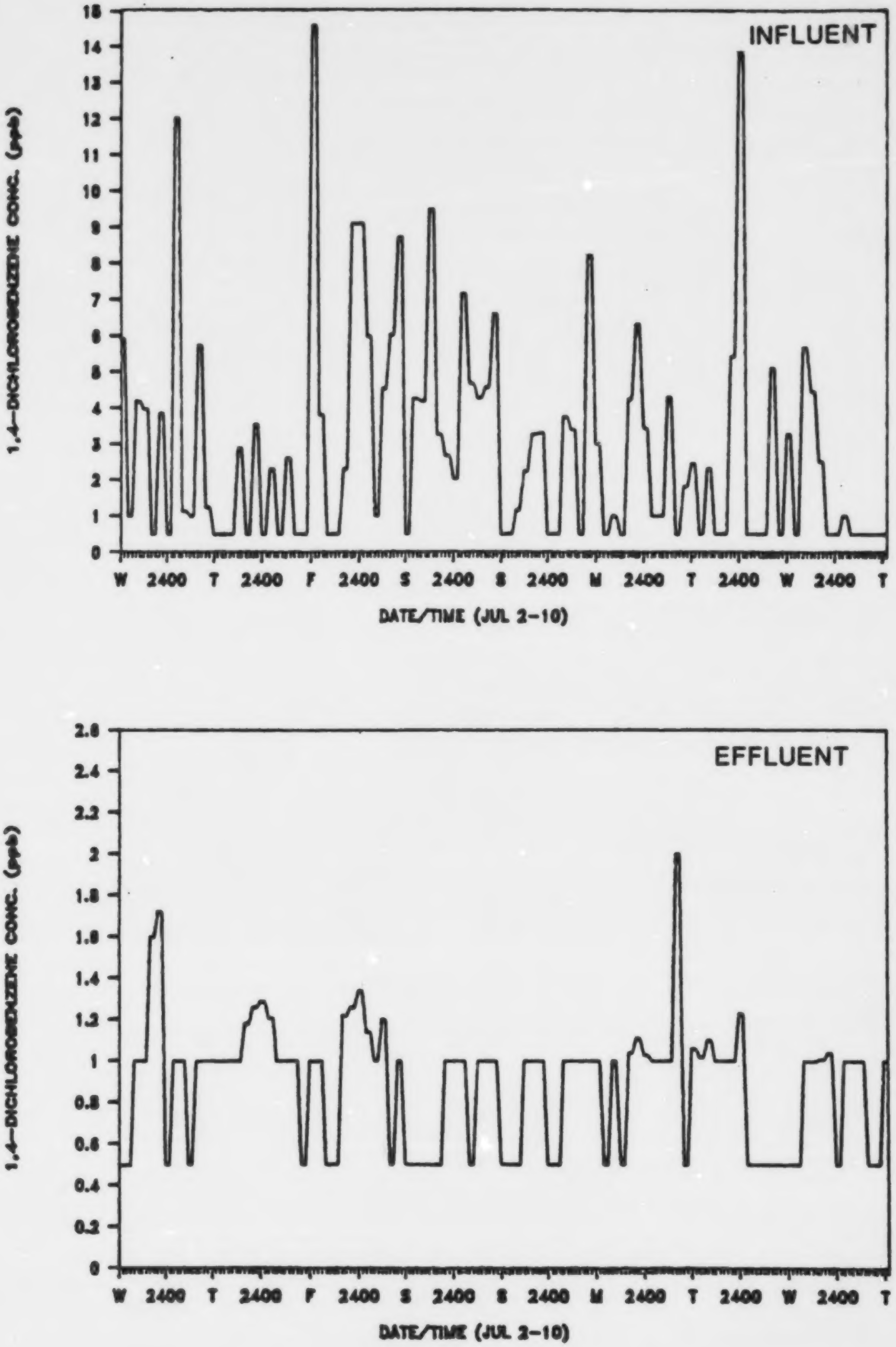


FIGURE 40: CHRONOLOGY OF INFLUENT AND EFFLUENT 1,4 - DICHLOROBENZENE AT WATERLOO WPCP

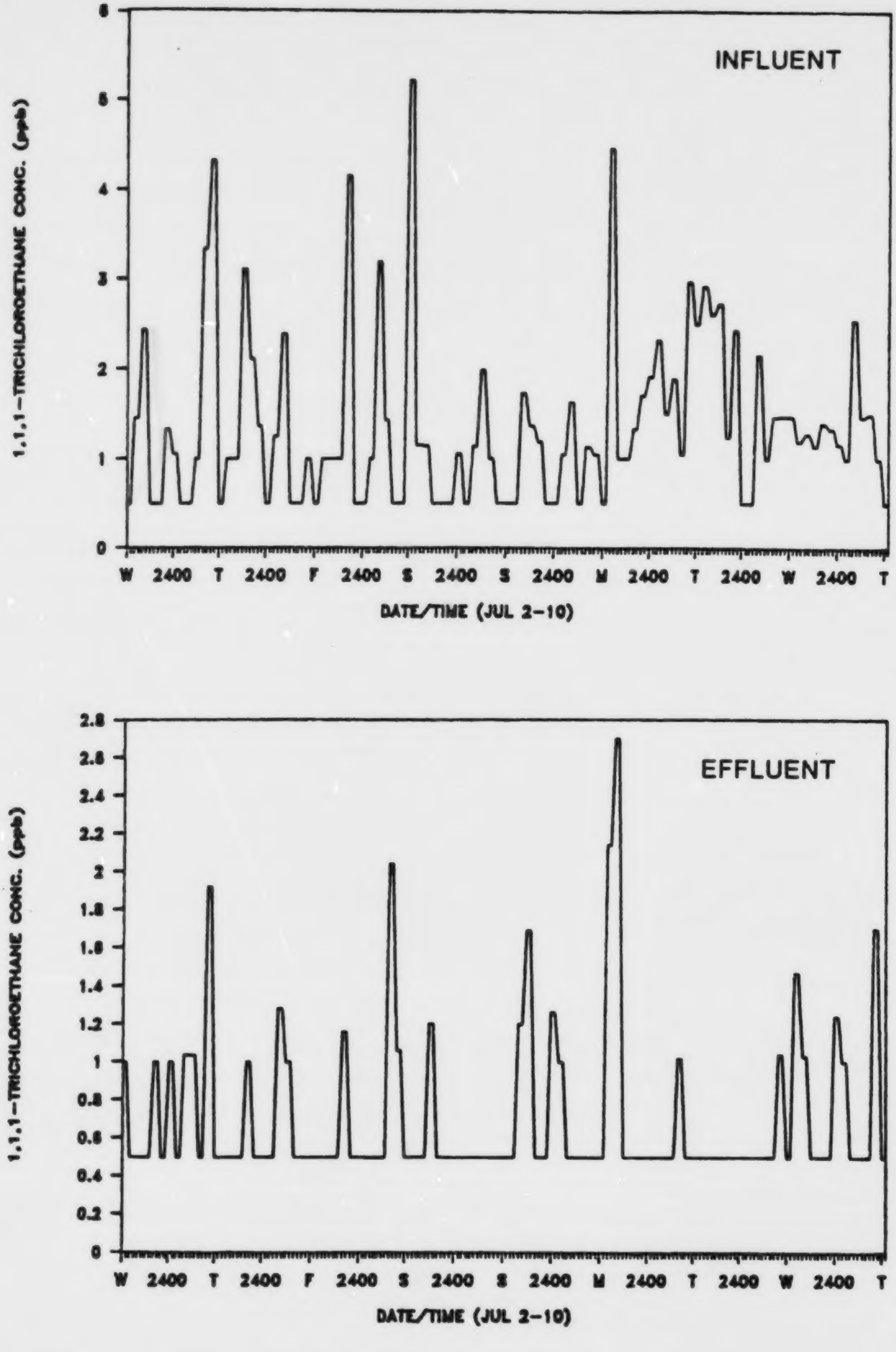


FIGURE 41: CHRONOLOGY OF INFLUENT AND EFFLUENT 1,1,1 - TRICHLOROETHANE AT WATERLOO WPCP

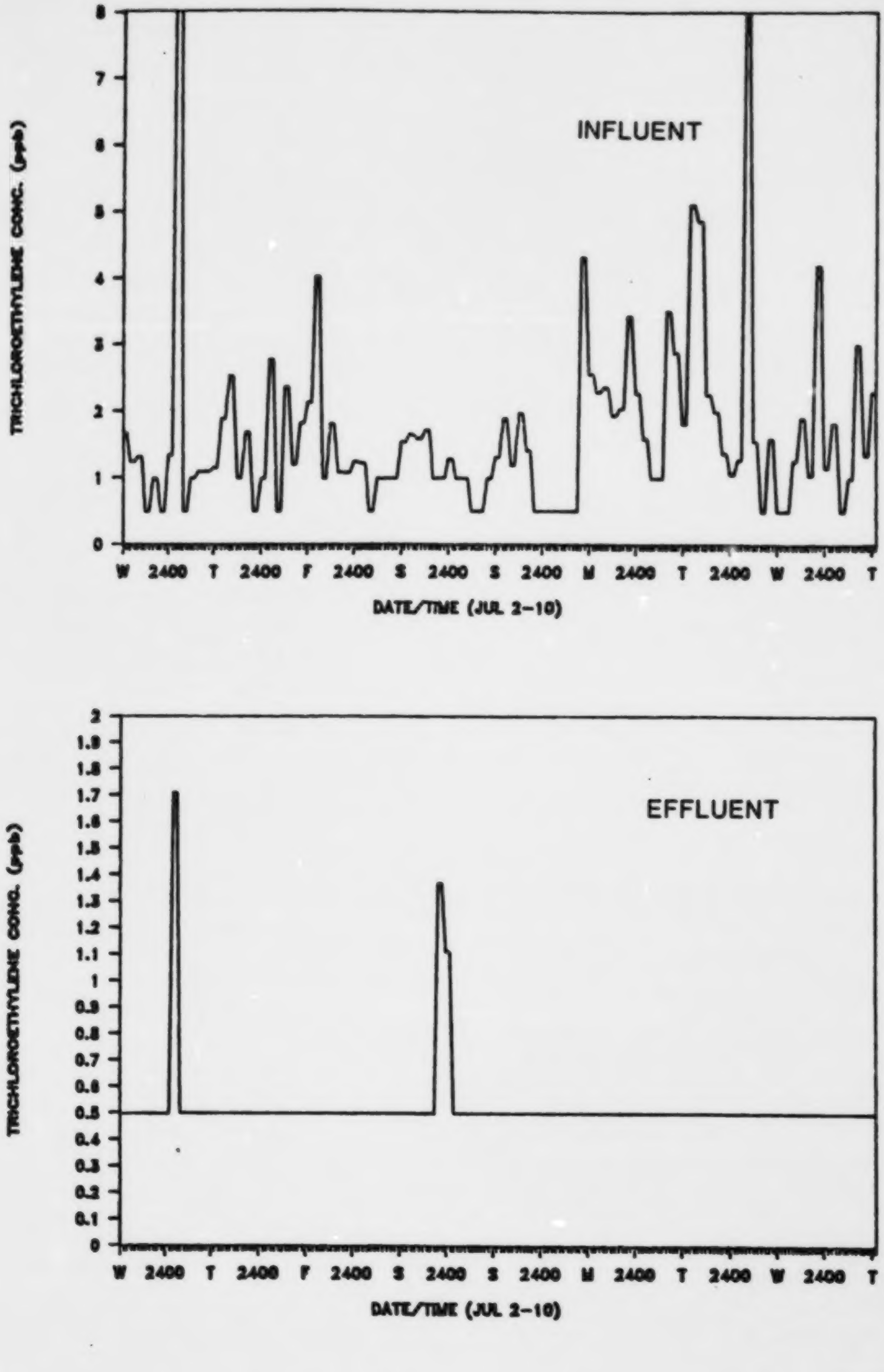


FIGURE 42: CHRONOLOGY OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE AT WATERLOO WPCP

effluents for all of these compounds, effluent sequences in general show no identifiable pattern. The raw sewage benzene concentration sequence (Figure 36) showed several peaks to concentrations of between 5 to 10 µg/L; however, there was no significant diurnal trend in the influent sequence. The other aromatic hydrocarbons, toluene (Figure 37) and xylene (Figure 38), showed similar non-diurnal influent variability with little effluent response. There was a slight but significant diurnal pattern in the influent chloroform concentration (Figure 39), but the remaining chlorinated volatiles (Figures 40, 41 and 42) showed no significant diurnal trends.

Removal of aromatic hydrocarbons was virtually complete as less than 10 percent of effluent samples contained detectable concentrations. Removal of chlorinated organics ranged from about 50 percent for 1,1,1-trichloroethane to about 80 percent for chloroform as summarized in Table 22.

Table 22
REMOVAL OF VOLATILE ORGANICS AT WATERLOO STP

	Removal (Percent) Based on	
Compound	Arithmetic Mean	Geometric Mean
Benzene	82	79
Toluene	94	91
p & m-xylene	99	90
Chloroform	81	71
1,1,1-trichloroethane	50	45
1,4-dichlorobenzene	69	53
Trichloroethylene	70	60

3.2.3.3 PAHs

Table 23 summarizes the frequency of detection of selected PAHs from raw wastewaters and final effluents from the Waterloo STP.

The most commonly identified PAH in the raw wastewater, based on HPLC methodology, was fluorene; however, confirmatory analysis by GC/MS showed that the HPLC identification was a false positive. Of the other PAHs, phenanthrene, fluoranthene and pyrene were detected at trace levels or greater in

Table 23
FREQUENCY OF DETECTION OF PAHs AT WATERLOO STP

	Frequency of Detection (%)					
	Influent			Effluent		
Compound	> MDL*	>Trace	Range (µg/L)	> MDL*	> Trace	Range (µg/L)
Acenaphthene	1	1	ND - 17.	2	2	ND - 64.
Acenaphthylene	7	7	ND - 33.	5	5	ND - 3.5
Anthracene	4	10	ND - 3.6	19	25	ND - 0.09
Phenanthrene	41	81	ND - 2.6	86	97	ND - 0.48
Benzo(a)anthracene	10	11	ND - 1.6	1	1	ND - 0.67
Chrysene	5	18	ND - 0.6	3	3	ND - 0.28
Benzo(b)fluoranthene	4	11	ND - 0.3	3	5	ND - 0.05
Benzo(k)fluoranthene	5	13	ND - 0.5	0	5	ND - Trace
Benzo(ghi)perylene	1	1	ND - 0.54	1	1	ND - 0.02
Dibenzo(ah)anthracene	0	0	ND	0	0	ND
Fluoranthene	15	31	ND - 1.1	4	0	ND - 0.08
Fluorene	81**	86	NA	8	12	ND - 1.6
Indeno(1,2,3-cd)pyrene	6	6	ND - 1.3	1	1	ND - 0.14
Naphthalene	14	17	ND - 8.4	5	5	ND - 0.53
Pyrene	9	23	ND - 0.9	4	5	ND - 0.09
Benzo(a)pyrene	7	13	ND - 0.55	1	3	ND - 0.03

*MDL varied from sample-to-sample depending on extraction volume and sample type but general was in the range 0.05 µg/L to 0.5 µg/L.
**GC/MS data indicate false identification.

more than 20 percent of raw wastewater samples. In the effluent samples, only anthracene (25 percent) and phenanthrene (97 percent) were detected at trace levels or higher in more than 20 percent of samples. The greater frequency of detection in effluent samples relates to the lower MDL achievable in these samples as compared to the raw wastewater samples. The frequency distribution for phenanthrene, the only PAH identified with any consistency in both influent and effluent samples, is presented in Figure 43. The geometric mean influent concentration was 0.25 µg/L, compared to a geometric mean effluent concentration of 0.08 µg/L, suggesting a removal efficiency of approximately 70 percent.

Recovery of the surrogate, terphenyl, from raw wastewaters and final effluents in the continuous flow extractors was relatively low. The average recovery in the raw wastewater was 27.4 percent (±10.1%). Recovery was similar in effluent

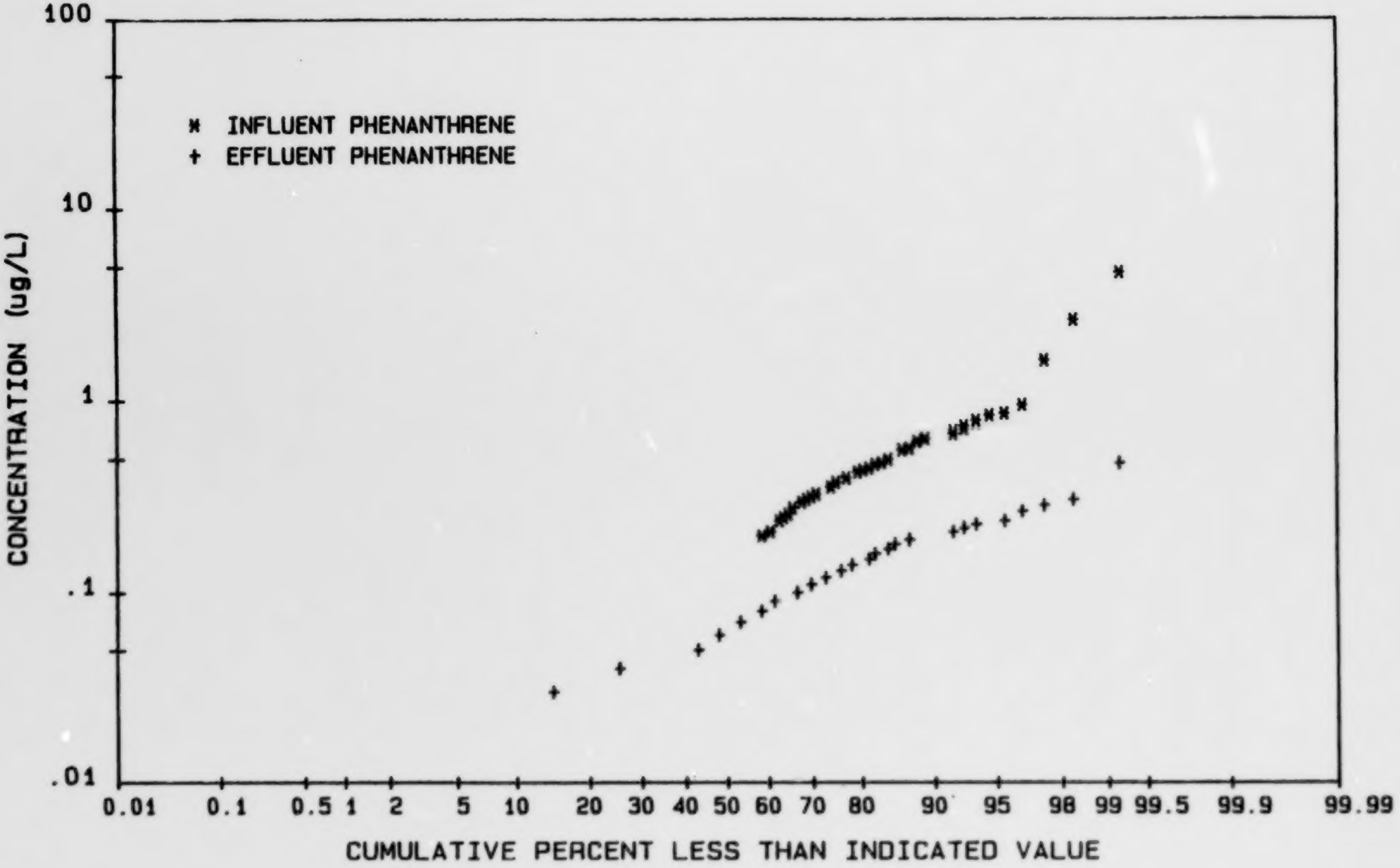


FIGURE 43 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT PHENANTHRENE CONCENTRATION AT WATERLOO STP

samples, averaging 33.0 percent (±10.3%). The reported PAH concentrations have not been corrected for analytical recovery.

3.3 Variability of Trace Contaminant Concentrations

The relative variability of influent and effluent concentrations of selected conventional contaminants, metals and trace organics is summarized in Table 24, where variability is reported both as the relative standard deviation (RSD, percent) and as the ratio of the 95th percentile concentration to the geometric mean.

FOC and TSS concentrations showed higher variability in the influent than in the effluent, indicating that the treatment facility produced a high degree of attenuation of the concentration of these contaminants. The opposite effect is apparent for total and filtered phosphorus; however, the interruption in chemical feed for phosphorus removal during the sampling period undoubtedly affected these data by significantly increasing the effluent variability. For the metal species, the influent-to-effluent RSD ratios for cadmium and lead suggest that the effluent was more variable than the influent; however, effluent concentrations for these contaminants were consistently near or at the detection limit which will impact on the validity of the effluent data analysis. The other metal species (chromium, copper, nickel and zinc), had influent-to-effluent variability ratios greater than one but considerably lower than the ratios for the conventional contaminants FOC and TSS. This suggests that there was a lesser degree of attenuation of these metals than was experienced for the conventional contaminants.

For the trace organics identified frequently in influents and effluents, the variability of the individual contaminant data in effluent samples was influenced by the generally low FOD of most contaminants. The data indicate that the degree of attenuation varied considerably between organic compounds. It also suggests that the extent of attenuation was generally higher for trace organics than for metals or conventional contaminants. A noteworthy exception appears to be total phenols which had essentially the same variability in influent and effluent samples.

Table 24
VARIABILITY OF INFLUENT AND EFFLUENT AT WATERLOO STP

Contaminant	Influent		Effluent		Influent:Effluent Ratio	
	RSD (%)	95th %ile Geo. Mean	RSD (%)	95th %ile Geo. Mean	RSD	95th %ile Geo. Mean
FOC	57.3	2.56	15.9	1.29	3.60	1.98
TSS	115.	2.93	34.5	1.65	3.33	1.78
Total P	29.0	1.39	40.0	1.96	0.73	0.71
Filt. P	43.2	1.89	63.9	2.81	0.67	0.67
Cadmium	24.4	1.36	44.2	1.46	0.55	0.93
Chromium	77.3	2.63	49.7	2.34	1.56	1.12
Copper	46.7	2.30	29.4	1.56	1.59	1.47
Nickel	37.3	1.69	36.4	1.43	1.02	1.18
Lead	99.0	4.78	110.	2.63	0.90	1.82
Zinc	51.5	2.38	38.5	2.03	1.34	1.17
Total Phenols	59.5	2.79	60.6	2.74	0.98	1.02
Benzene	94.1	3.93	3.3	1.67	28.5	2.35
Chloroform	220.	6.18	70.0	3.00	3.14	2.06
1,1,1-trichloroethane	71.4	3.00	57.1	2.83	1.25	1.06
Toluene	146.	5.00	66.7	1.67	2.19	2.99
p, m-xylene	685.	6.36	75.0	3.67	9.13	1.73
1,4-dichlorobenzene	103.	5.35	33.3	1.63	3.09	3.28
Trichloroethylene	88.2	3.31	40.0	1.00	2.21	3.31
Phenanthrene	147.	3.36	80.6	3.38	1.82	0.99

To more rigorously compare the variability of the conventional compounds, metals and organics, the normalized variance of each group of compounds in influents and effluents was calculated (by dividing each individual concentration by the mean value for that particular contaminant in that stream) and statistically compared by an F-test. The normalized variances are presented in Table 25. Analysis of these data showed that for all classes of contaminants, effluent concentrations were significantly less variable than influent concentrations, although the difference for metal species at the Waterloo STP was marginal. Organics showed by far the greatest variability in influents, but metal contaminants were less variable at Waterloo than the conventional contaminants. Similarly, organic contaminants exhibited the highest degree of effluent variability. Conventional contaminants had the lowest degree of variability in the effluent despite the unusually high variability of phosphorus species related to the ferrous chloride feed interruption.

Table 25
COMPARISON OF INFLUENT AND EFFLUENT VARIABILITY
AT WATERLOO STP

	Normalized Variance	
Contaminant Group	Influent	Effluent
Conventionals*	0.478	0.174
Metals**	0.350	0.315
Organics***	6.452	0.519

---

* Conventionals includes FOC, TSS, TP, Filt. P

** Metals includes Cd, Cr, Cu, Ni, Pb, Zn

*** Organics includes total phenols, benzene, chloroform, 1,1,1-trichloroethane, toluene, p&m-xylene, 1,4-dichlorobenzene, trichloroethylene and phenanthrene

The criterion which was established at project initiation to determine that a contaminant exhibited a significant degree of variability was based on the 95th percentile concentration exceeding the geometric mean by a factor of 2.0. Based on this criterion, both FOC and TSS exhibited significant variability in the influent but neither were significantly variable in the Waterloo STP effluent. Of the metal species, four (chromium, copper, lead and zinc) exhibited significant variability in the influent to the Waterloo STP but only three (chromium, lead and zinc) exceeded the variability criterion in the Waterloo STP effluent. All of the organic species summarized in Table 24 exceeded the variability criterion in the influent to the Waterloo STP. In the effluent, only phenols, chloroform, 1,1,1-trichloroethane, p&m-xylene and phenanthrene met the criterion.

3.4 Toxicity of Influents and Effluents

The results of the 48-hour Daphnia and 96-hour rainbow trout static acute toxicity bioassays performed on the Waterloo STP raw influent, unchlorinated secondary and final chlorinated effluents are shown in Table 26. Mortality generally occurred within the first 24 hours of the testing period.

In all samples, temperature and dissolved oxygen levels remained stable throughout the exposure time at 15±1°C and above 8 mg/L respectively, while the pH values increased slightly in all samples.

The chemical characteristics of the initial parameters of the effluents tested appears in Table 27. The low oxygen levels were elevated to the reported test concentrations after agitation resulting from mixing dilution water with the test solution.

3.4.1 Species Sensitivity

Four influent samples were tested with both Daphnia and rainbow trout. Daphnia showed greater sensitivity than trout with only one sample (04 July, high load), and trout were more sensitive than Daphnia with two samples (06 July, high load and low load). The fourth sample was non-lethal

Table 26
RESULTS OF ACUTE LETHALITY TESTING PERFORMED ON THE SEWAGE TREATMENT PLANTS EFFLUENT SAMPLES

Date/Time	Undiluted Treated/Chlorinated			LC50 (95% Confidence Limits)						
				Plant Influent		Secondary		Treated/Chlorinated		
	Total NH_3-N (mg/L)	NH_3 (mg/L)	TRC (mg/L)	Daphnia (% v/v)	Trout (% v/v)	Daphnia (% v/v)	Trout (% v/v)	Daphnia (% v/v)	Trout (% v/v) (BEAK)	Trout (% v/v) (MOE)
High Waste Load Condition										
02 July 86/12:00	1.7	0.05	0.24	80 (59-100)	-	N.L.	-	N.L.	-	
04 July 86/10:00	1.85	0.05	0.05	26 (23-30)	39 (50-100)	N.L.	N.L.	N.L.	N.L.	
05 July 86/10:00	3.2	0.05	0.20	-	-	-	-	N.L.	-	
06 July 86/10:00	1.75	0.05	0.12	84 (67-100)	38 (34-43)	N.L.	N.L.	N.L.	N.L.	
08 July 86/10:00	1.7	0.07	0.10	-	-	-	-	N.L.	-	
09 July 86/10:00	3.5	0.14	0.27	9 (7-11)	-	N.L.	-	N.L.	-	
10 July 86/10:00	1.7	0.05	0.22	N.L.	-	N.L.	-	N.L.	-	
Low Waste Load Condition										
03 July 86/04:00	1.00	0.05	0.05	N.L.	-	N.L.	-	N.L. (20)*	-	
04 July 86/04:00	1.05	0.05	0.17	N.L.	N.L	N.L.	N.L	N.L.	N.L.	
05 July 86/04:00	4.0	0.06	0.02	-	-	-	-	N.L.	-	
06 July 86/04:00	1.4	0.05	0.05	N.L.	71	N.L.	N.L.	N.L.	N.L	
08 July 86/04:00	1.5	0.05	0.05	-	-	-	-	N.L.	-	
09 July 86/04:00	3.5	0.05	0.12	52 (40-67)	-	N.L.	-	N.L.	-	
10 July 86/04:00	1.5	0.05	0.16	N.L. (10)*	-	N.L.	-	N.L.	-	

TRC = Total residual chlorine measured by DPD method.
Total NH_3-N = Total ammonia nitrogen measured by Nesslerization method.
NH_3 = Un-ionized ammonia; calculated according to Emmerson et al. (1975).
LC50 = Median lethal concentration.
N.L. = Non-lethal.
* = Some mortality observed.

Table 27

INITIAL PHYSICAL AND CHEMICAL PARAMETERS OF THE UNDILUTED EFFLUENT SAMPLES FROM THE WATERLOO SEWAGE TREATMENT PLANT

Sample	Date/Time Sample Collected	Oxygen (mg/L)	pH	Conductivity (umhos/cm)	Temperature (°C)	Chlorine (mg/L)	Ammonia (mg/L)
Influent	02.07.86/12:00	0.8	7.97	2,150	21		
	03.07.86/04:00	0.6	6.59	2,010	21		
	04.07.86/04:00	0.8	6.58	2,020	17		
	04.07.86/10:00	0.9	6.87	2,050	15		
	06.07.86/04:00	5.2	7.17	3,650	15		
	06.07.86/10:00	2.4	7.04	2,370	15		
	09.07.86/04:00	0.8	6.99	1,960	21		
	09.07.86/10:00	0.7	6.98	1,900	21		
	10.07.86/04:00	0.6	8.50	2,160	20		
	10.07.86/10:00	0.4	7.41	1,620	20		
Secondary Effluent	02.07.86/12:00	5.2	7.17	1,970	21		
	03.07.86/04:00	5.7	7.06	2,210	21		
	04.07.86/04:00	5.8	7.09	2,550	20		
	04.07.86/10:00	5.3/5.8	7.15/7.07	2,100/2,230	20/17		
	06.07.86/04:00	5.2	7.04	1,873	15		
	06.07.86/10:00	4.0	7.15	1,820	15		
	09.07.86/04:00	5.8	7.46	2,040	21		
	09.07.86/10:00	5.8	7.97	1,230	21		
	10.07.86/04:00	3.7	7.33	1,568	20		
	10.07.86/10:00	4.8	7.41	1,730	20		
Treated/Chlorinated Effluent	02.07.86/12:00	5.6	7.21	1,950	21	0.24	1.7
	03.07.86/04:00	5.9	6.99	1,925	21	0.05	1.0
	04.07.86/04:00	5.8	7.00	1,912	18.5	0.17	1.05
	04.07.86/10:00	5.5	7.17	1,970	15	0.05	1.85
	05.07.86/04:00	5.8	7.51	2,170	20	0.02	4.0
	05.07.86/10:00	5.6	7.49	2,100	21	0.20	3.2
	06.07.86/04:00	5.0	6.84	1,743	15	0.05	1.4
	06.07.86/10:00	4.8	7.11	1,772	15	0.12	1.75
	08.07.86/04:00	5.6	7.64	2,100	21	0.10	1.7
	08.07.86/10:00	5.8	7.98	2,100	21	0.10	1.7
	09.07.86/04:00	5.5	7.29	2,110	21	0.12	3.5
	09.07.86/10:00	5.5	7.91	1,950	21	0.27	3.5
	10.07.86/04:00	5.0	7.25	1,690	20	0.16	1.5
	10.07.86/10:00	5.3	7.23	1,760	20	0.22	1.7

to both organisms. Although the data are limited, there was no clear relationship between the sensitivities of the two organisms.

3.4.2 Waste Loading and Treatment

Four of the five influent samples tested during 'high load' conditions were lethal to *Daphnia* compared to only one out of five influent samples tested during 'low' load indicating that influent was more toxic during high loadings to the plant. Non-chlorinated and chlorinated secondary treated effluent was essentially non-lethal and did not require any detoxification. Secondary treatment of toxic influent rendered the wastewater non-lethal.

3.4.3 Ammonia

The most obvious compound likely to produce toxicity was ammonia. However, influent concentrations were not measured, since the focus at this stage of program development was on the toxicity of the discharged effluent and the incremental toxicity expressed after chlorination. As was seen in Table 26, the effluent samples were non-lethal before and after chlorination to both *Daphnia* and trout.

Ammonia concentrations have been expressed in the un-ionized (NH_3), more toxic form derived from the total ammonia concentrations and the pH conditions of the tests. Rainbow trout 96-hour LC50's have been reported in the literature to range from 0.2 to 0.8 mg un-ionized ammonia/L, depending on pH testing conditions. *Daphnia magna* tend to be much more tolerant of un-ionized ammonia, with 48-hour LC50's reported between 2 to 3 mg/L(14). Review of the un-ionized ammonia in the effluent indicates that none of the ammonia levels exceeded documented lethal concentrations for rainbow trout or *Daphnia*.

3.4.4 Chlorine

The second most obvious toxicant measured is chlorine. However, since no lethality was observed, there was clearly insufficient TRC present or available for the duration of exposure to be lethal.

Arthur et al(15) clearly identified the greater sensitivity of fish (brook trout, coho salmon, fathead, sucker, walleye) to chlorinated sewage effluent than invertebrates (gammarus, stonefly, caddisfly, crayfish, snails). The 7-day LC50 values for fish ranged from 0.08 to 0.26 mg TRC/L, and for invertebrates from 0.2 to greater than 0.8 mg TRC/L. Larson et al(16) identified that trout (coho salmon, brook trout, cutthroat trout) may live indefinitely at TRC concentrations near 0.05 mg/L.

Review of the TRC measurements of chlorinated effluent indicates that none of the levels exceeded the range of documented lethal values, although some were close (02, 05, 09, 10 July, 'high load'; 04, 09, 10 July 'low load').

3.4.5 Other Contaminants

A brief summary of toxic levels of contaminants monitored as part of the parallel analytical program to trout and Daphnia was prepared and is presented in Table 28. The concentrations of these contaminants in the Waterloo STP samples are summarized in Table 29 and Table 30 for inorganics and organics, respectively.

3.5 Prediction of Waterloo STP Influent Quality

3.5.1 Description of HAZPRED Model

HAZPRED is an interactive, microcomputer-based model capable of predicting the concentrations of hazardous contaminant concentrations in sewage collection systems(30). The model has a number of levels of sophistication which can be selected depending on the objective of the prediction.

The first version of HAZPRED was developed in 1984 and was designed to predict the nature, concentration and loading of HCs in dry weather sanitary sewage flow only. This Phase I program allowed the user to evaluate a particular catchment at either of two levels of sophistication. Both model levels used the same basic approach, in that wastewater quantities and HC concentrations were predicted from the summed concentrations of the following wastewater components:

Table 28
DOCUMENTED TOXIC CONCENTRATIONS (μg/L) OF VARIOUS METALS AND ORGANICS TO FISH AND INVERTEBRATES

	Blue Book Maximum(29)	Rainbow Trout LC50's	Daphnia LC50's
Inorganics			
Cd(17,18)	0.2	100-2,000	65
Cr(19)	10	3,400-65,500	435-58,700
Cu(17)	5	20-102	80-85
Ni(20)	25	32,000	510-1,120
Pb(17,21)	5-25	1,000-6,500	450
Zn(17,18)	30	135-7,210	100-280
Phosphorus	10-20		
Organics			
Benzene(22)	50*	9,200	
Chloroform(27)		23,900-36,500	
1,4-Dichlorobenzene(23)		1,120-1,200	11,000
Ethylbenzene(22)	1,400*	14,000	
Phenols	1		
Tetrachloroethylene(26,28)		13,400-20,300	17,700
Toluene(22,24)	500*	24,000	313
1,1,1-Trichloroethane(28)		42,300-52,900	
Trichloroethylene(25,28)		42,300-52,900	85,200
Xylene(22)	100*	8,200-13,500	

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*Tentative PWQO values under consideration by MOE

- Residential wastewater
- Commercial wastewater
- Industrial process and sanitary wastewater
- Industrial cooling water
- Dry weather infiltration

Level I methodology used total industrial water-use data and applied a constant factor to estimate industrial wastewater flows. In the Level I procedures, no distinction was made between industrial cooling waters and process wastewaters.

Table 29
CONCENTRATIONS OF INORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFLUENTS (μg/L)

Date	pH	P		P(filt.)		Cd		Cr		Cu		Ni		Pb		Zn	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																	
02.07.86	7.2	7,070	820	3,900	770	4	4	74	20	118	13	24	17	105	5	339	55
04.07.86	7.2	10,500	850	3,690	310	5	4	58	25	141	7	26	20	30	5	163	71
05.07.86	7.5	6,970	990	4,000	380	6	5	33	26	105	9	22	25	5	5	138	85
06.07.86	7.4	6,510	1,070	3,380	500	4	5	29	21	93	13	20	22	10	5	88	43
08.07.86	8.0	7,210	1,930	3,850	1,380	6	6	53	35	110	17	41	41	15	5	156	83
09.07.86	7.9	6,930	750	3,840	230	4	4	58	19	149	14	26	23	35	5	153	87
10.07.86	7.5	7,290	710	4,000	190	4	4	43	27	156	12	23	23	30	5	227	67
Low Loading																	
03.07.86	7.0	2,630	930	1,080	540	3	4	37	29	77	10	20	23	10	10	81	109
04.07.86	7.0	7,800	800	2,000	500	3	5	65	64	50	13	19	25	5	5	110	111
05.07.86	7.5	3,390	1,100	1,850	500	5	4	32	22	55	14	24	27	10	5	69	104
06.07.86	7.3	3,210	1,000	1,540	540	6	6	29	21	46	13	21	23	5	5	51	50
09.07.86	7.4	3,030	1,030	620	380	6	5	38	29	115	15	25	27	70	70	143	77
10.07.86	7.5	3,140	830	620	270	4	3	29	24	82	11	19	24	5	5	112	79

* No samples were acutely lethal to Daphnia magna nor Salmo gairdneri.

Table 30
CONCENTRATIONS OF ORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFFLUENT (μg/L)*

Sample Date	Phenolics		Benzene		Chloroform		1,4-Dichlorobenzene		1,1,1-Trichloroethane		Trichloroethylene		Toluene		P&M-Xylene	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
02.07.86		3.7	1.24	0.50	1.03	1.96	5.92	0.50	0.50	1.00	1.68	0.50	4.03	0.25	118.86	0.25
04.07.86	14.3	1.1	0.68	0.25	1.98	0.50	0.50	0.50	1.00	0.50	1.83	0.50	2.73	0.50	302.4	0.25
05.07.86	35.9	6.9	1.33	0.50	9.49	1.84	8.73	1.00	0.50	1.06	1.00	0.50	2.86	0.50	7.74	0.50
06.07.86		1.3	0.61	0.25	0.50	0.50	6.60	1.00	0.50	0.50	1.00	0.50	1.35	0.25	2.77	0.25
08.07.86	22.8	4.0	0.59	0.25	5.75	1.63	1.82	0.50	2.98	0.50	2.89	0.50	4.44	1.03	17.14	0.50
09.07.86	34.4	1.5	0.80	0.25	5.41	0.50	0.50	0.50	1.48	1.04	1.60	0.50	2.76	0.25	14.23	0.25
10.07.86		2.2	1.32	0.25	2.21	1.80	0.50	0.50	1.00	1.70	1.35	0.50	3.41	0.25	4.76	0.25
Low Loading																
03.07.86	15.0	3.7	1.23	0.25	0.50	0.50	1.13	1.00	0.50	1.04	0.50	0.50	6.69	0.50	7.23	0.50
04.07.86	7.4	2.8	0.50	0.25	1.98	0.50	0.50	1.00	2.39	1.28	0.50	0.50	1.06	0.25	5.06	0.25
05.07.86	1.0	3.3	1.06	0.25	2.48	0.50	1.00	1.00	3.20	0.50	0.50	0.50	5.91	0.25	3.26	0.50
06.07.86	3.3	1.7	1.15	0.25	1.41	0.50	4.67	0.50	1.14	0.50	1.00	0.50	1.37	0.25	2.72	0.50
09.07.86	8.7	1.2	5.53	0.25	5.44	2.64	0.50	0.50	2.16	0.50	8.04	0.50	5.07	0.25	12.23	1.00
10.07.86	34.0	6.2	1.72	0.25	4.19	0.50	0.50	1.00	2.56	0.50	0.50	0.50	9.20	0.25	3.99	2.14

* No samples were acutely lethal to _Daphnia magna_ nor _Salmo gairdneri_.

Level II methodology incorporated refinements to the prediction of industrial wastewater quantity by regarding cooling water and process water separately. This enabled prediction of the wastewater characteristics of individual industrial groups as defined by their Standard Industrial Classification (SIC) code.

Phase II development of the HAZPRED Model included the capability to predict the presence, concentration and loading of HCs in wet weather flows, specifically stormwater runoff and combined sewer overflow. These enhancements to the Phase I program were completed in November, 1985. The enhancements made to HAZPRED allowed the program to be used as an impact assessment tool for both separate and combined sewer areas.

3.5.2 Application of HAZPRED to Waterloo STP Influent

The dry weather flow component of HAZPRED Phase II was utilized to predict the concentrations of selected trace contaminants in the influent to the Waterloo STP. The industrial contributions were based on data provided by the Regional Municipality of Waterloo and summarized in Table 4. Commercial and residential water consumption records from the local utility were used to define these components of the STP influent. From the flow, industrial SIC and the industrial/commercial/residential wastewater characterization data contained in HAZPRED, concentrations of heavy metals including cadmium, chromium, copper, lead, nickel and zinc were predicted. For organics, only the concentration of compounds found at a high frequency in the raw wastewater were predicted. This list was limited to chloroform, toluene, benzene and trichloroethylene. Data for xylene isomers, 1,4-dichlorobenzene and 1,1,1-trichloroethane which were also detected frequently in the Waterloo influent, were not contained in HAZPRED.

Table 31 compares the predicted and observed geometric mean concentrations for the selected compounds, along with the logarithmic ratio of the values. With the exception of zinc, the observed concentration was within an order-of-magnitude (ratio < ± 1.0) of the predicted value. HAZPRED predicted very high influent zinc concentrations (2.1 mg/L), possibly due to the significant metal finishing contribution to the Waterloo influent. The lower than predicted value probably indicates that a significant degree of pretreatment is practiced by the tributary industries, at least in terms of zinc discharges.

Table 31
COMPARISON OF PREDICTED AND OBSERVED INFLUENT CONCENTRATIONS AT WATERLOO STP

Contaminant	Concentration (μg/L) Observed	Concentration (μg/L) Predicted	Log Ratio
Chloroform	2.8	4.31	-0.19
Toluene	3.4	8.71	-0.41
Benzene	1.4	1.91	-0.13
Trichloroethylene	1.3	5.01	-0.59
Cadmium	4.4	3.58	0.09
Chromium	46.7	96.09	-0.31
Copper	110	54.33	0.31
Lead	13.6	89.01	-0.82
Nickel	26	16.75	0.19
Zinc	135	2126.82	-1.20

The HAZPRED model underestimated the total flow to the Waterloo STP based on the input data. The predicted flow was approximately 32,718 m^3/d compared to a measured average flow of 39,350 m^3/d during the sampling period. HAZPRED also predicted a high extraneous flow component, 9840 m^3/d. Based on the lower flows and the generally higher concentrations predicted by the HAZPRED, the contaminant loadings predicted by HAZPRED for contaminants in Table 31 would be in closer agreement with the actual loadings at the Waterloo STP than the observed and predicted concentrations.

4.0 WELLAND STP RESULTS

4.1 Plant Operation and Performance

During the intensive sampling period at the Welland STP (August 19 to August 27), operating conditions and performance were representative of typical historic plant conditions. The only unusual occurrences were abnormally high flow meter readings from about 02:00 hr until 10:00 hr on August 22 which were caused by partial blockage of the bar screens, creating submergence in the throat of the flume. For the purposes of data analysis, flow rates for this period were calculated as the average value of flows on weekdays (Monday to Friday) without significant precipitation. On August 25 commencing at about 16:00 hr, there appeared to be a discharge of industrial waste to the plant from an unidentified source. The raw wastewater had an elevated pH (10.3) and was orange-coloured. High phosphorus concentrations were evident during this period (refer to Section 4.2.1) and foaming occurred on the pre-aeration tanks. The industrial discharge was apparent until about 21:00 hours on August 25.

Plant flow and influent and effluent quality data for the period August 18 to August 31 encompassing the intensive sampling period are summarized in Table 32. These data are comparative to long-term performance data for the Welland facility (Table 7).

Table 32
WELLAND STP PERFORMANCE
(August 19 - August 31, 1986)

Average Daily Flow (m^3/d)	33,541
Influent Quality	
BOD_5 (mg/L)	126
TSS (mg/L)	166
TP (mg/L)	2.6
Effluent Quality	
BOD_5 (mg/L)	14
TSS (mg/L)	9
TP (mg/L)	0.69

Average daily flow during this two week period was slightly lower than the annual average, 33,541 m³/d compared to 37,960 m³/d, but typical of dry weather conditions. Four rainfall events occurred during this time period. Influent TSS concentrations were typical of the long-term average. The influent BOD_5 concentration was higher than normally observed and influent TP concentrations were lower; however, both of these estimates were based on only one sample during the time period. Effluent quality compared well with the long-term average in terms of BOD_5, TSS and TP concentrations.

Average operating conditions for this two week period are summarized in Table 33 based on plant operating data. These are also typical of long-term conditions (Table 8), although the estimated SRT was considerably shorter than the SRT measured during this monitoring program. Based on mixed liquor and waste sludge samples collected during the intensive monitoring period, the plant operated at an average SRT of 7.7 days.

Table 33
AVERAGE OPERATING CONDITIONS AT WELLAND STP
(August 19 - August 31, 1986)

MLSS (mg/L)	2070
F/M (kg/kg MLSS.d)	0.25
D.O. Range	0.6 - 2.0
SVI (Avg.)	206

4.2 Intensive Sampling Program Results

4.2.1 Conventional Contaminants

A probability distribution of Welland STP raw sewage flow data during the sampling period is presented in Figure 44, based on total plant flow recorded at 2-hour intervals from August 19 to August 27. Geometric mean flow during this period was 30,570 m³/d and flow followed a typical diurnal pattern as shown in Figure 45. Very high plant flows (at or

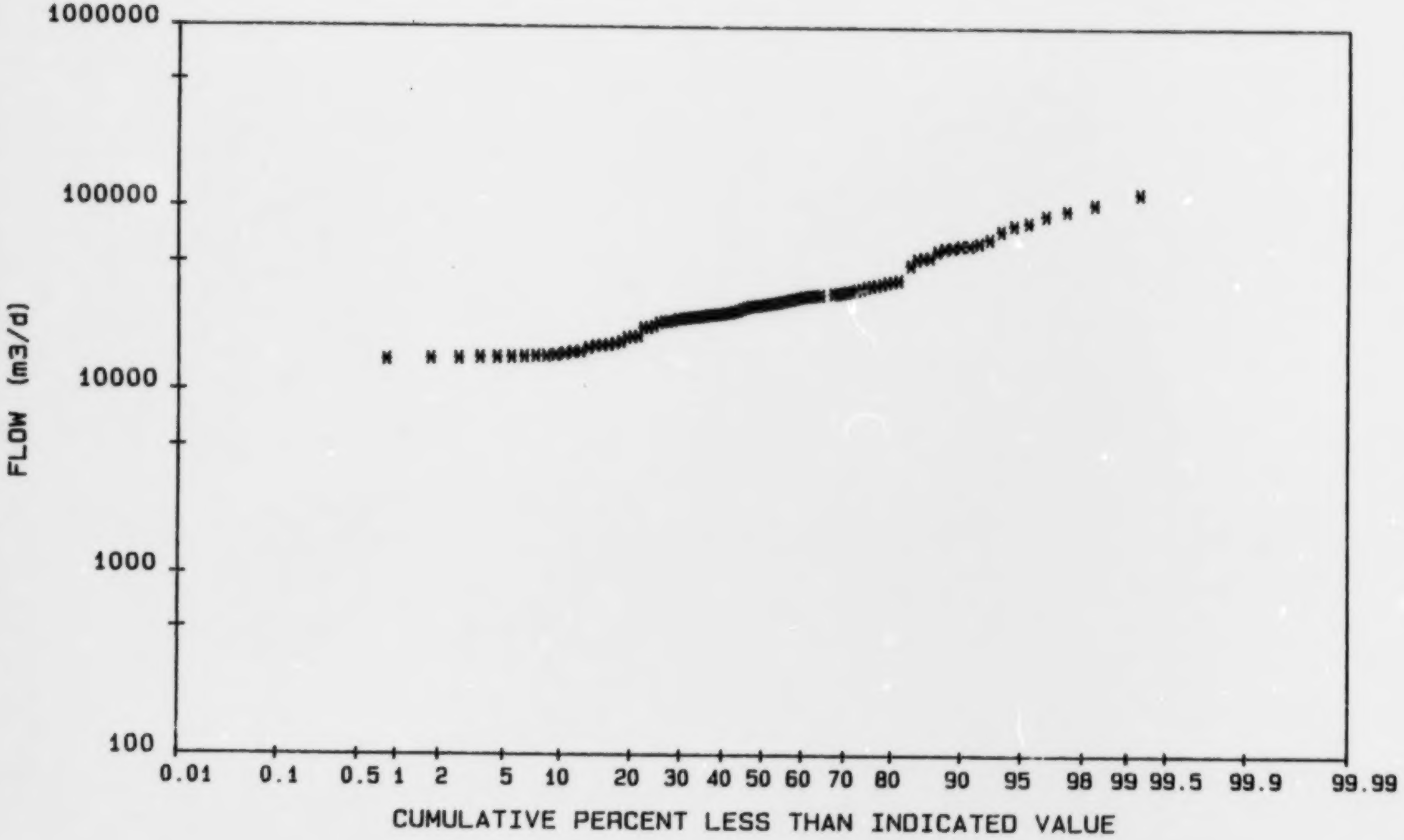


FIGURE 44 PROBABILITY DISTRIBUTION OF FLOW DATA AT WELLAND STP

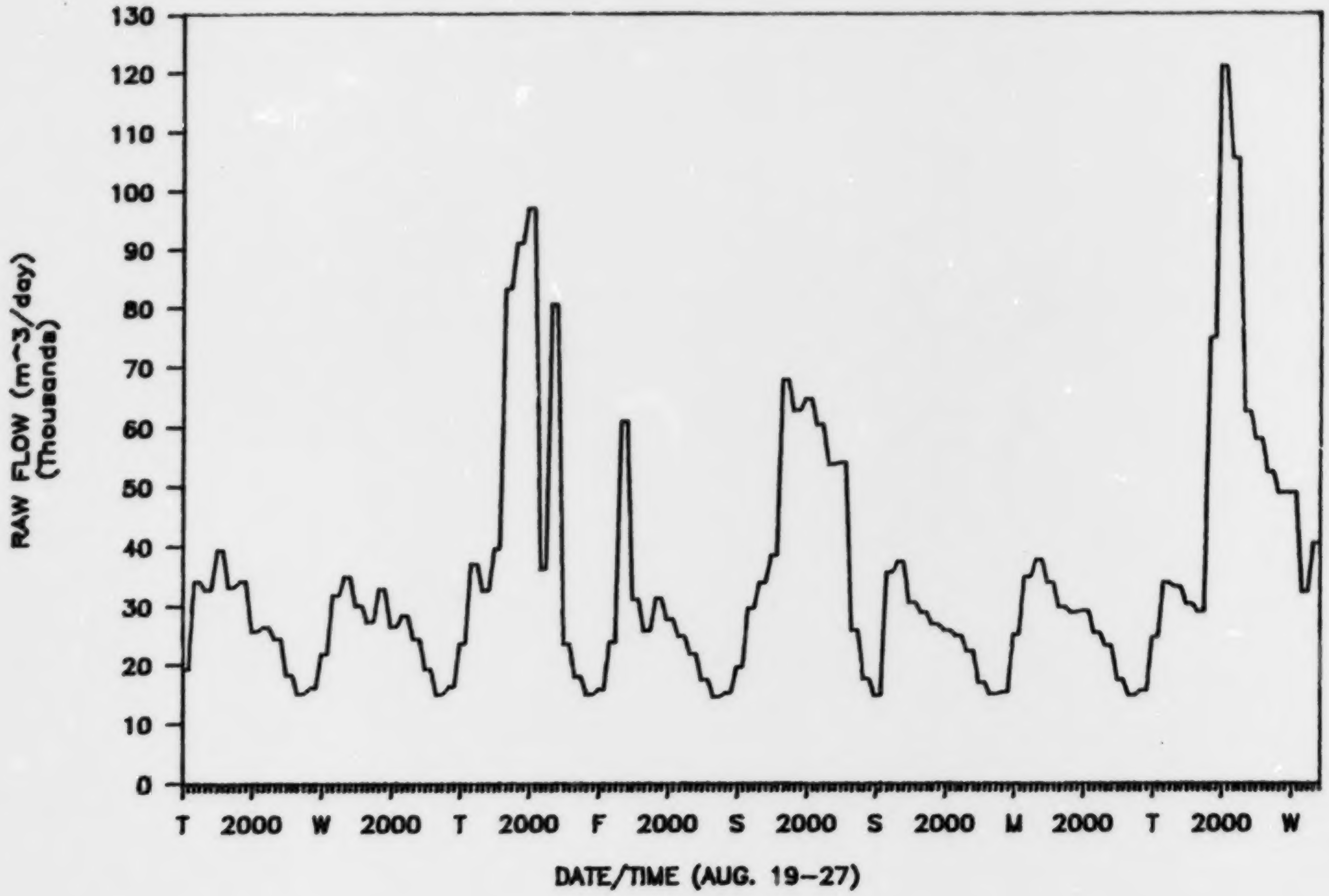


FIGURE 45: CHRONOLOGICAL FLOW PATTERN AT WELLAND WPCP

exceeding 100,000 m^3/d) were recorded on August 21 and August 26, corresponding to periods of precipitation. Higher than average flows were also experienced on August 22 and August 23, which also corresponded to rainfall events.

Probability distributions for influent and effluent FOC, influent TKN and effluent NH_3-N, influent and effluent TSS and influent and effluent total and filtered phosphorus are presented in Figures 46 to 50, respectively. Key statistical data for these conventional contaminants are summarized in Table 34. The intensive plant sampling data suggest better plant performance in terms of effluent BOD_5 and TSS concentrations than plant data which were based on manually-collected 16 hour non-flow proportioned composite samples. The data also indicate that a significant amount of nitrification was occurring at the plant, with effluent ammonia concentrations of 4.0 mg/L compared to influent concentrations of TKN which averaged 21.4 mg/L.

Chronological plots of FOC concentrations in the influent and effluent (Figure 51) and TSS concentrations (Figure 52) show that the influent strength followed a typical diurnal pattern. However, both the FOC and TSS concentrations in the raw wastewater exhibited periodic high levels (FOCs approaching 100 mg/L and TSS exceeding 250 mg/L) which were not correlated to each other or to high flow events related to periods of precipitation. There was no apparent diurnal pattern in the effluent FOC concentrations as it appeared that removal of organics was virtually complete under all conditions and there was little variability in the effluent FOC concentrations (RSD = 11.0 percent). Effluent TSS concentrations (3.8 mg/L ±1.8 mg/L) were at near detection limits. At these concentrations, the resolution of the analytical method (±1 mg/L) was such that no discernible pattern could be identified. On two occasions, higher concentrations (>10 mg/L) were observed which were directly related to high flow ($\geq$ 100,000 m^3/d) events. Influent total and filtered phosphorus concentrations (Figures 53 and 54, respectively) also showed a significant diurnal trend, but, in both cases, rainfall events on August 21, August 23 and August 26 were apparent in terms of a dilution effect on the raw sewage concentrations. There was no significant diurnal pattern in the effluent concentrations of either total or filtered phosphorus. An elevated concentration of both total

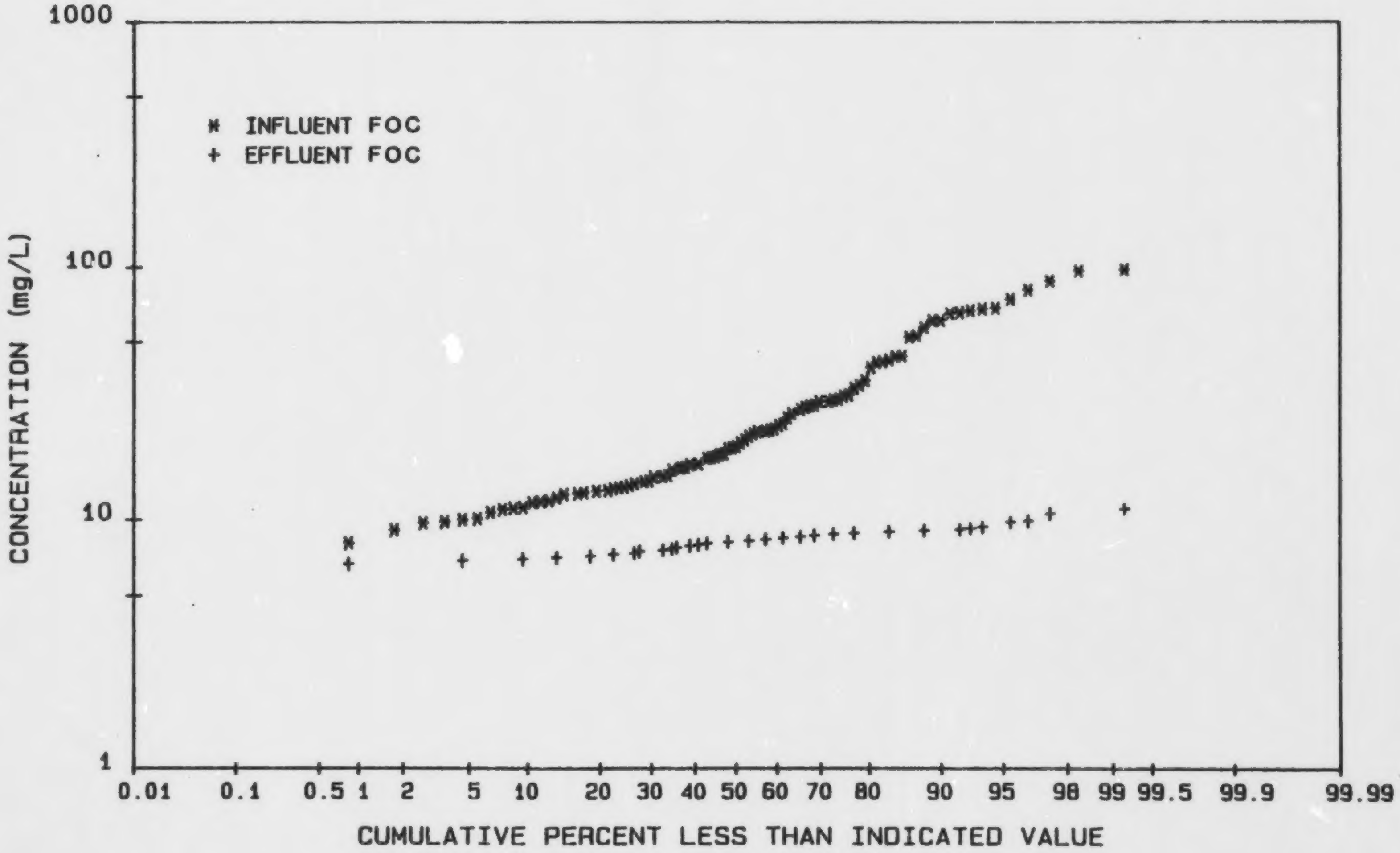


FIGURE 46 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FOC CONCENTRATION AT WELLAND STP

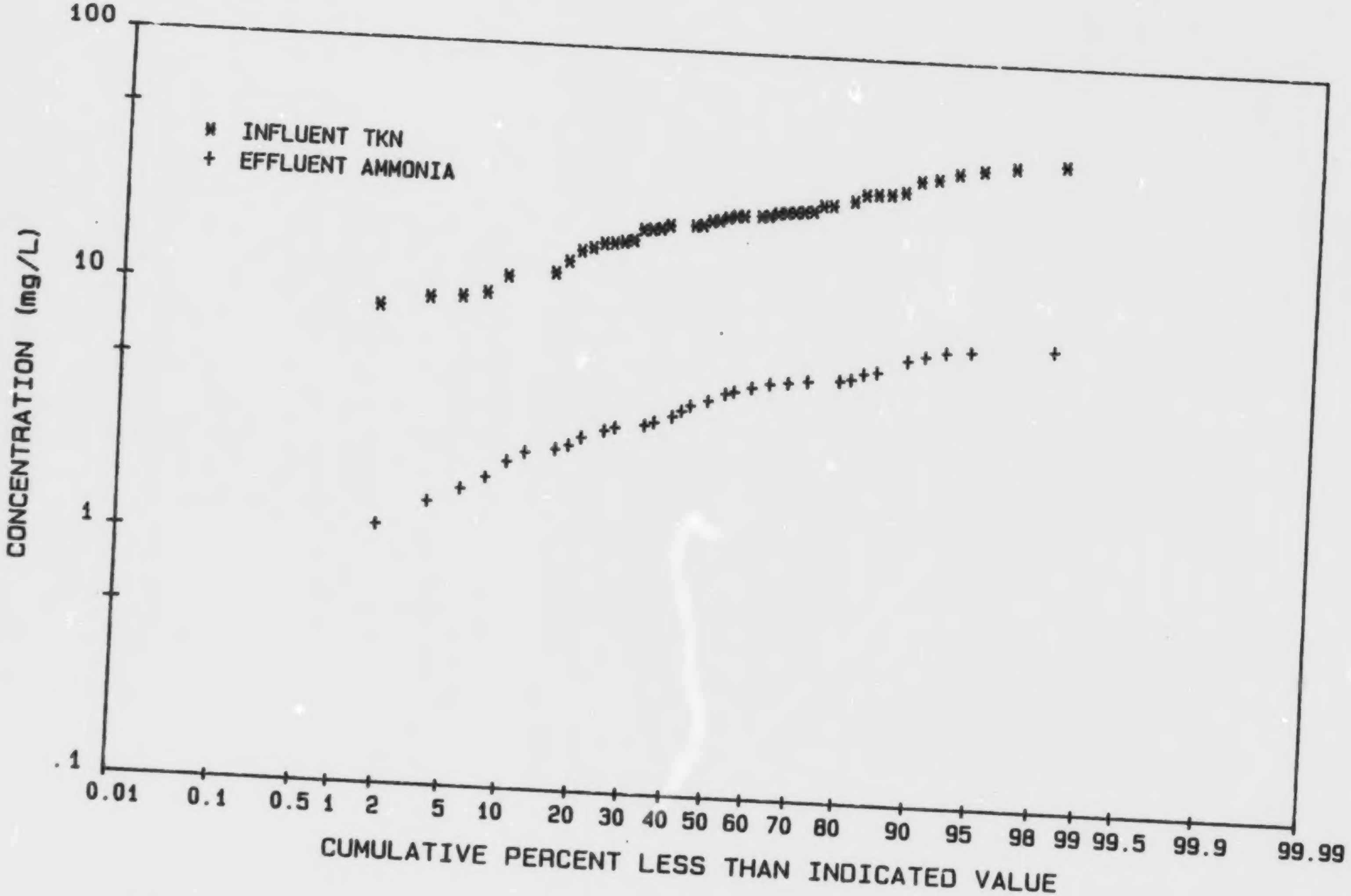


FIGURE 47 PROBABILITY DISTRIBUTION OF INFLUENT TKN AND EFFLUENT AMMONIA CONCENTRATION AT WELLAND STP

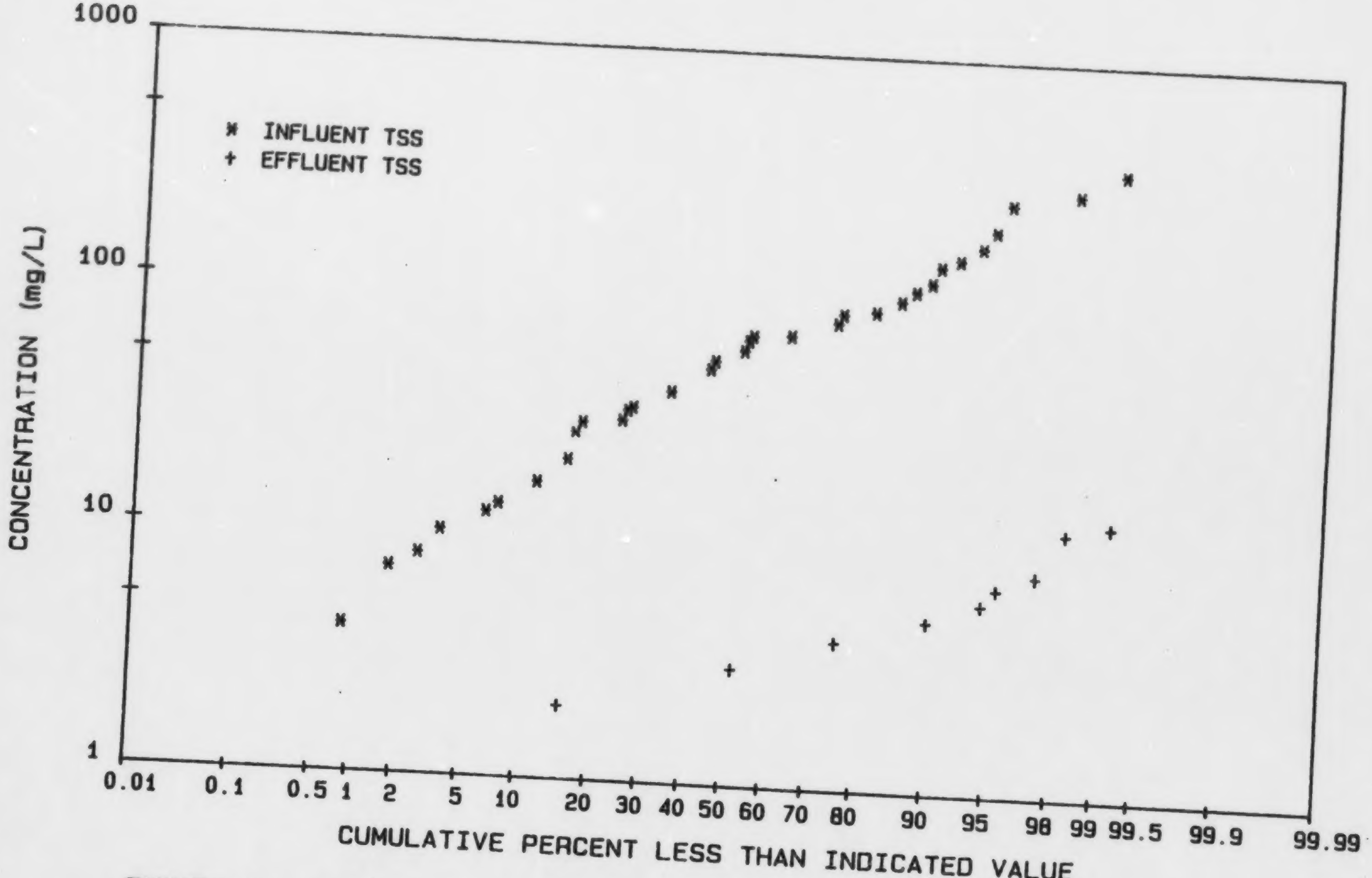


FIGURE 48 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TSS CONCENTRATION AT WELLAND STP

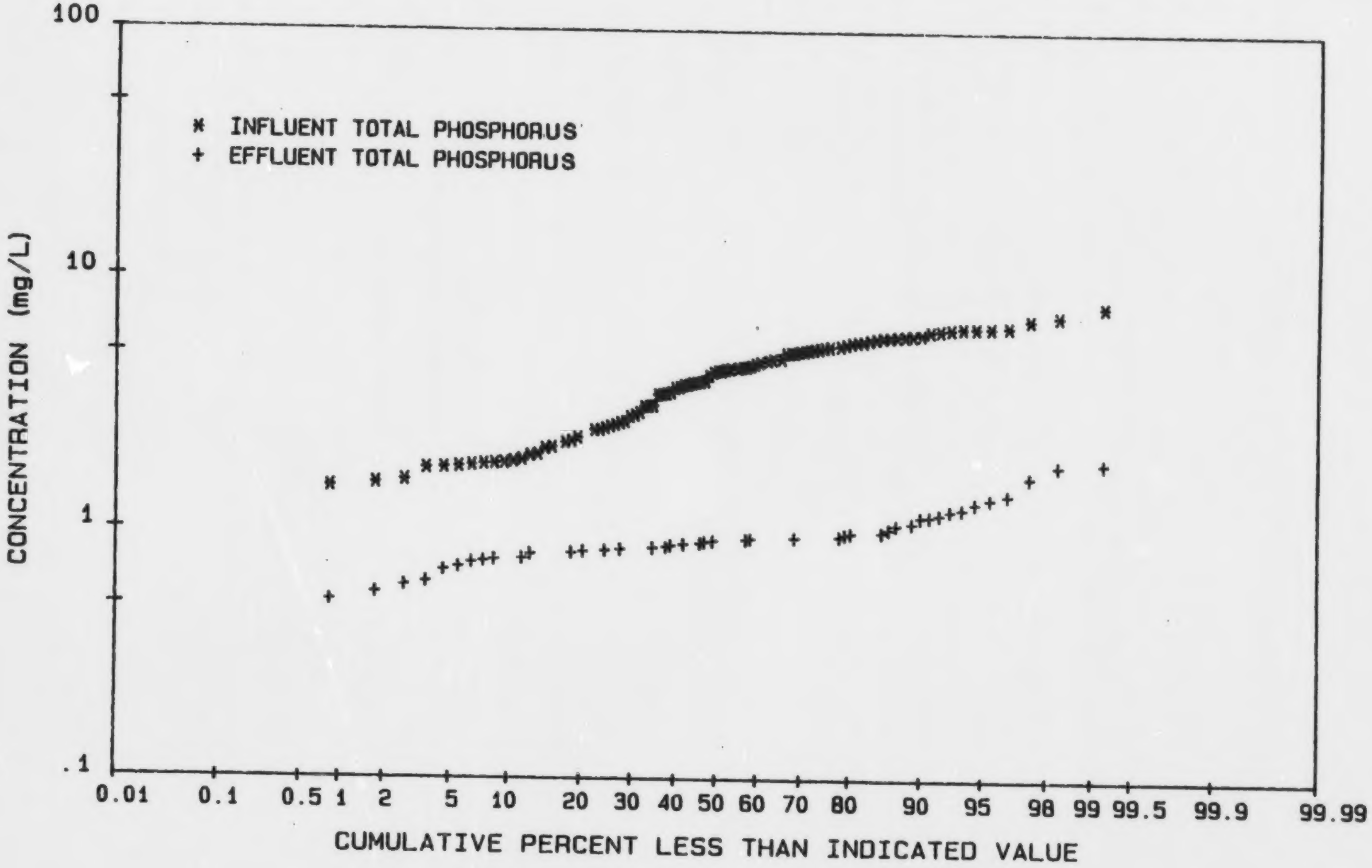


FIGURE 49 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOTAL PHOSPHORUS CONCENTRATION AT WELLAND STP

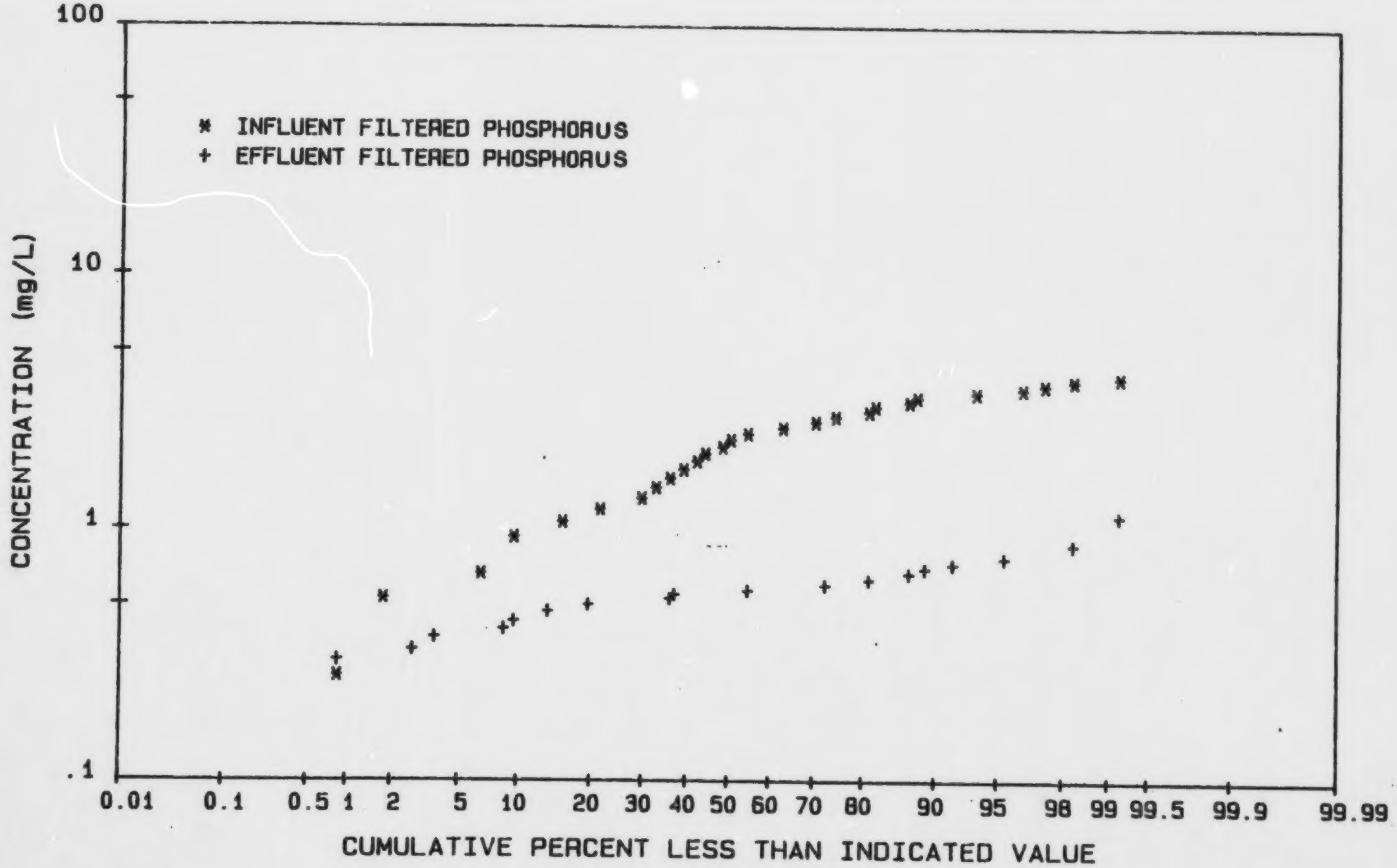


FIGURE 50 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FILTERED PHOSPHORUS CONCENTRATION AT WELLAND STP

Table 34
CONVENTIONAL CONTAMINANT DATA FOR WELLAND STP

	Influent						Effluent					
Parameter*	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
BOD_5	9	87.5	101.0	58.5	57.9	-	9	2.4	2.4	0.5	20.8	-
FOC	99	22.6	28.0	20.9	74.6	74.4	99	8.2	8.2	0.9	11.0	9.6
TSS	99	53.5	73.9	65.0	88.0	228.	99	3.5	3.8	1.8	47.4	6.2
TP	99	3.70	4.07	1.61	39.6	6.7	99	0.91	0.93	0.21	22.6	1.3
Filt. P	99	1.90	2.14	0.94	43.9	3.6	99	0.60	0.59	0.13	22.0	0.8
TKN	50	20.0	21.4	7.73	36.0	-	9	4.51	4.98	2.39	48.0	-
NH_3-N	9	14.1	14.8	4.78	32.3	-	50	3.51	3.95	1.74	44.1	-

*All concentrations reported in mg/L. RSD reported in %.

(KIR21/272W)

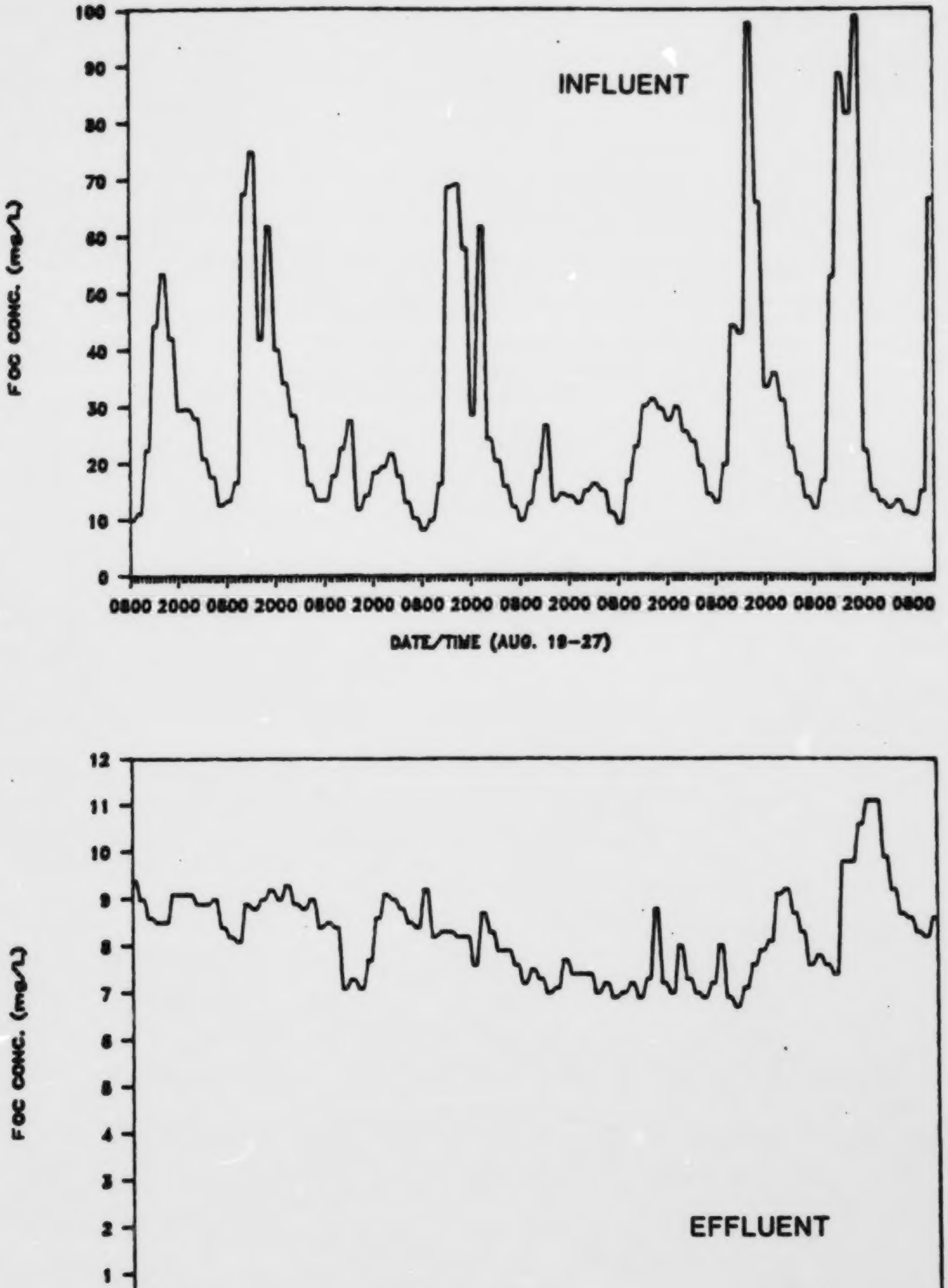
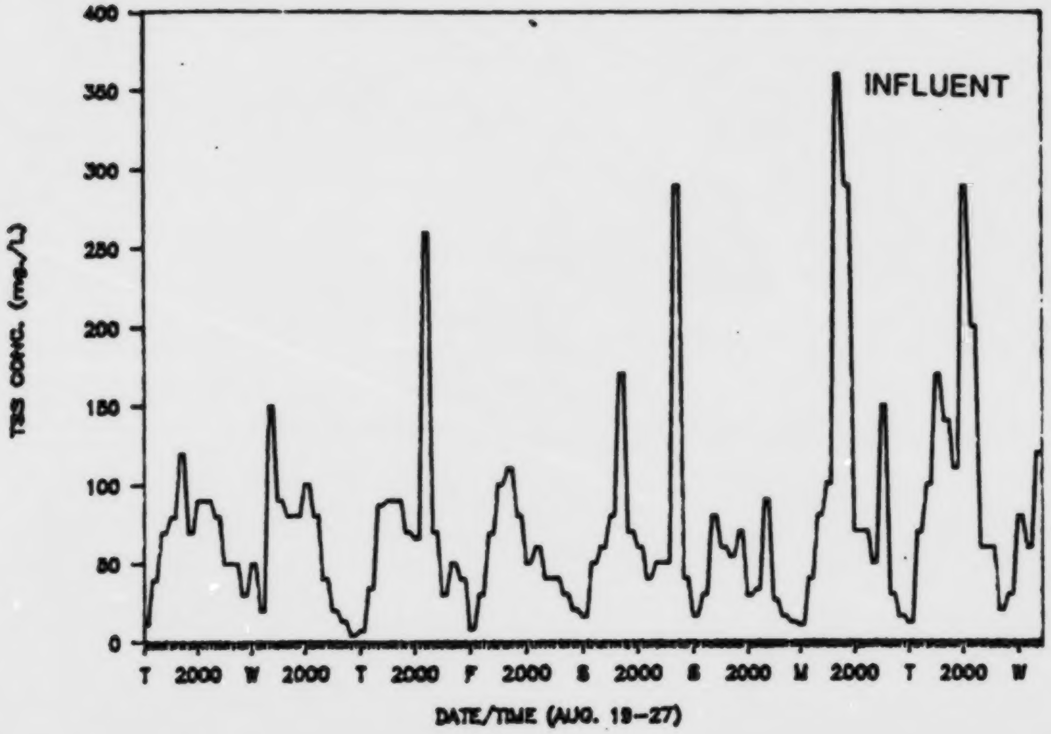


FIGURE 51: CHRONOLOGY OF INFLUENT AND EFFLUENT FOC AT WELLAND WPCP



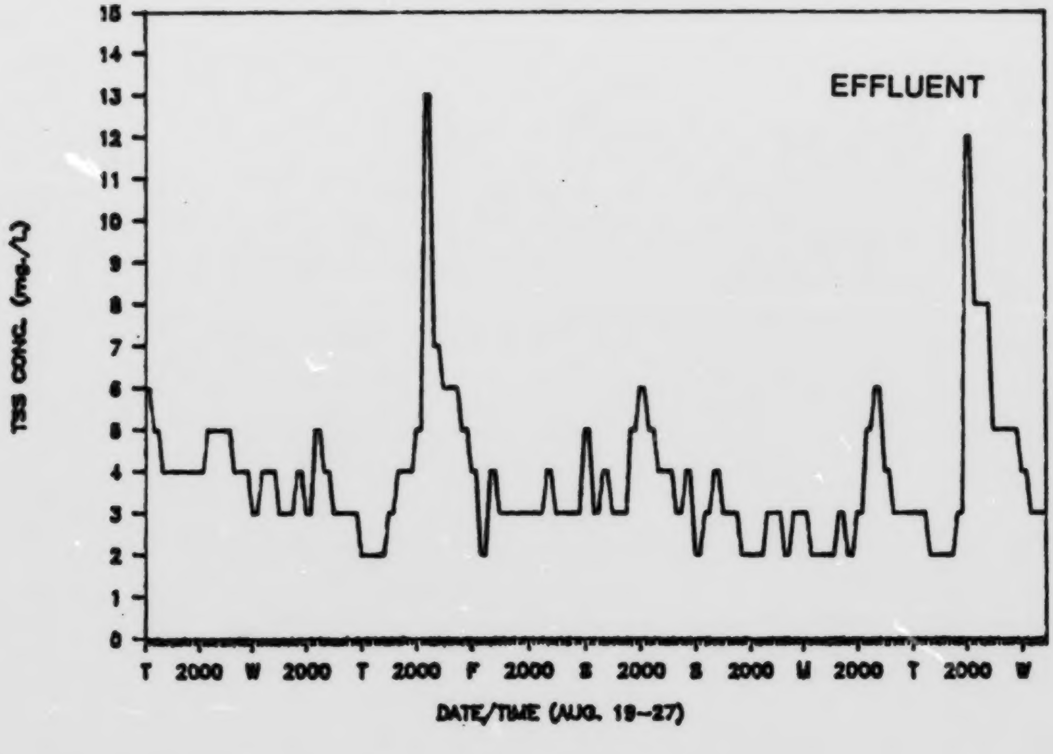


FIGURE 52: CHRONOLOGY OF INFLUENT AND EFFLUENT TSS AT WELLAND WPCP

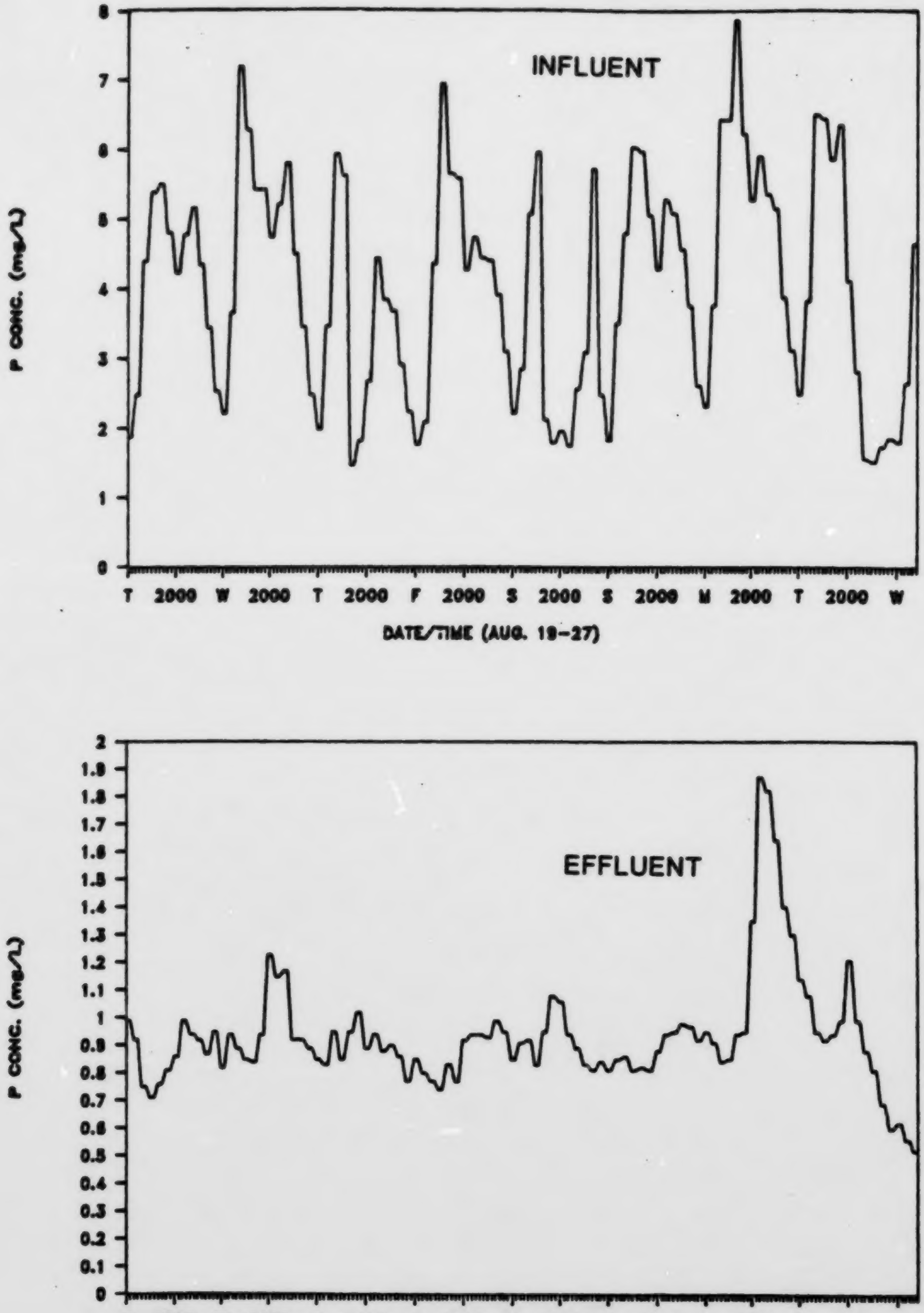


FIGURE 53: CHRONOLOGY OF INFLUENT AND EFFLUENT P AT WELLAND WPCP

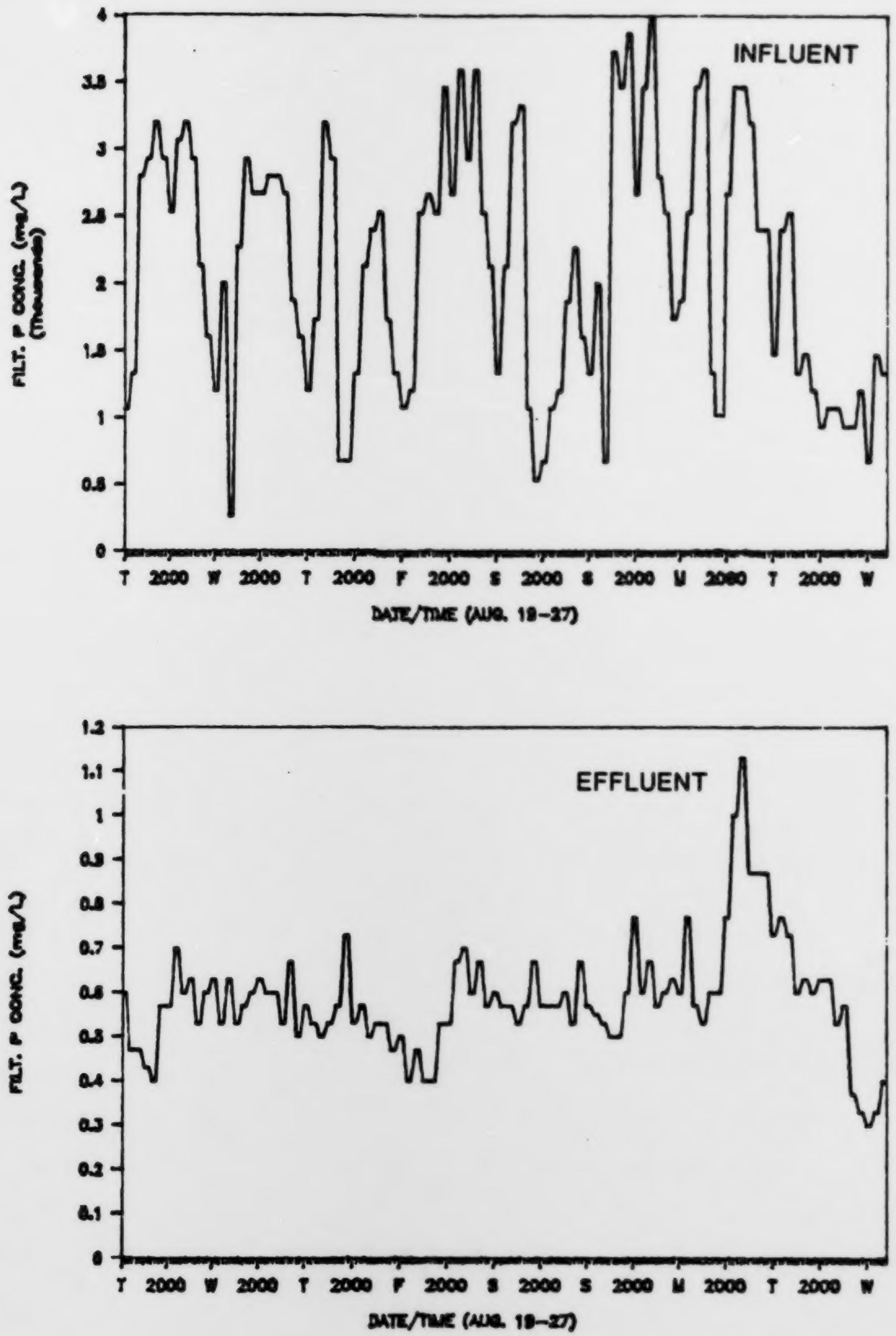


FIGURE 54: CHRONOLOGY OF INFLUENT AND EFFLUENT FILT. P AT WELLAND WPCP

and soluble phosphorus concentrations occurred on August 25 at approximately 24:00 hours. This high concentration was not correlated to high flow or to high effluent TSS concentrations but occurred at the same time as the discharge of industrial waste to the plant referred to in Section 4.1. Influent phosphorus levels were not significantly elevated, but the unidentified industrial waste may have been a factor contributing to the higher effluent concentrations.

4.2.2 Metals

Probability distributions of influent and effluent concentrations of cadmium, chromium, copper, nickel, lead and zinc are presented in Figures 55 to 60, respectively. Key statistics describing these distributions are summarized in Table 35. As was the case at the Waterloo STP, copper and zinc were present in the raw wastewater at higher concentrations than the other metals; however, the concentrations of all metals were lower, on an average basis, at Welland than at Waterloo despite the higher industrial load on the collection system. Effluent concentrations of all metals were also lower at Welland than at Waterloo. As noted in Section 3, the apparent paucity of data for some contaminants in these probability distributions reflects the number of discrete concentration values identified.

Chronological plots of influent and effluent metal concentrations are presented in Figures 61 to 66. Influent and effluent concentrations of cadmium (Figure 61) were generally in the range from 1 μg/L to 5 μg/L and the resolution of the analytical method was ±1 μg/L. Thus, no discernible patterns or effects could be identified.

Influent chromium concentrations showed significant variability (RSD = 56 percent) with occasional peak concentrations exceeding 30 μg/L (Figure 62). There was no significant diurnal trend in the influent concentration sequence. Effluent concentrations averaged less than 10 μg/L. The lack of resolution of the analytical method at these concentrations (±1 μg/L) is evident in the effluent concentration sequence. No significant diurnal trend was apparent but there was a correlation between influent and effluent concentrations at the Welland STP.

Raw sewage copper concentrations showed a significant diurnal variation (Figure 63) but this pattern was not apparent

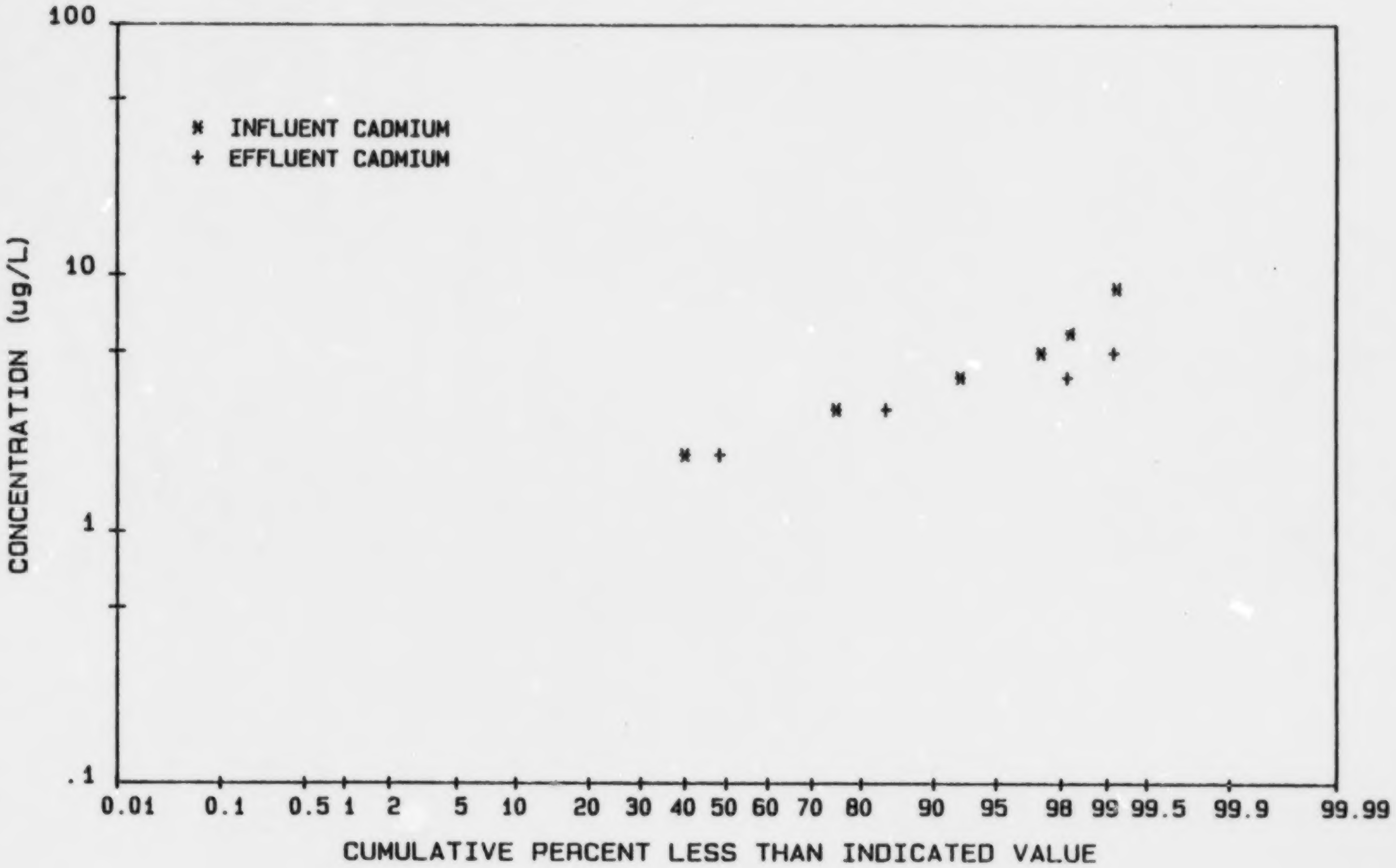


FIGURE 55 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CADMIUM CONCENTRATION AT WELLAND STP

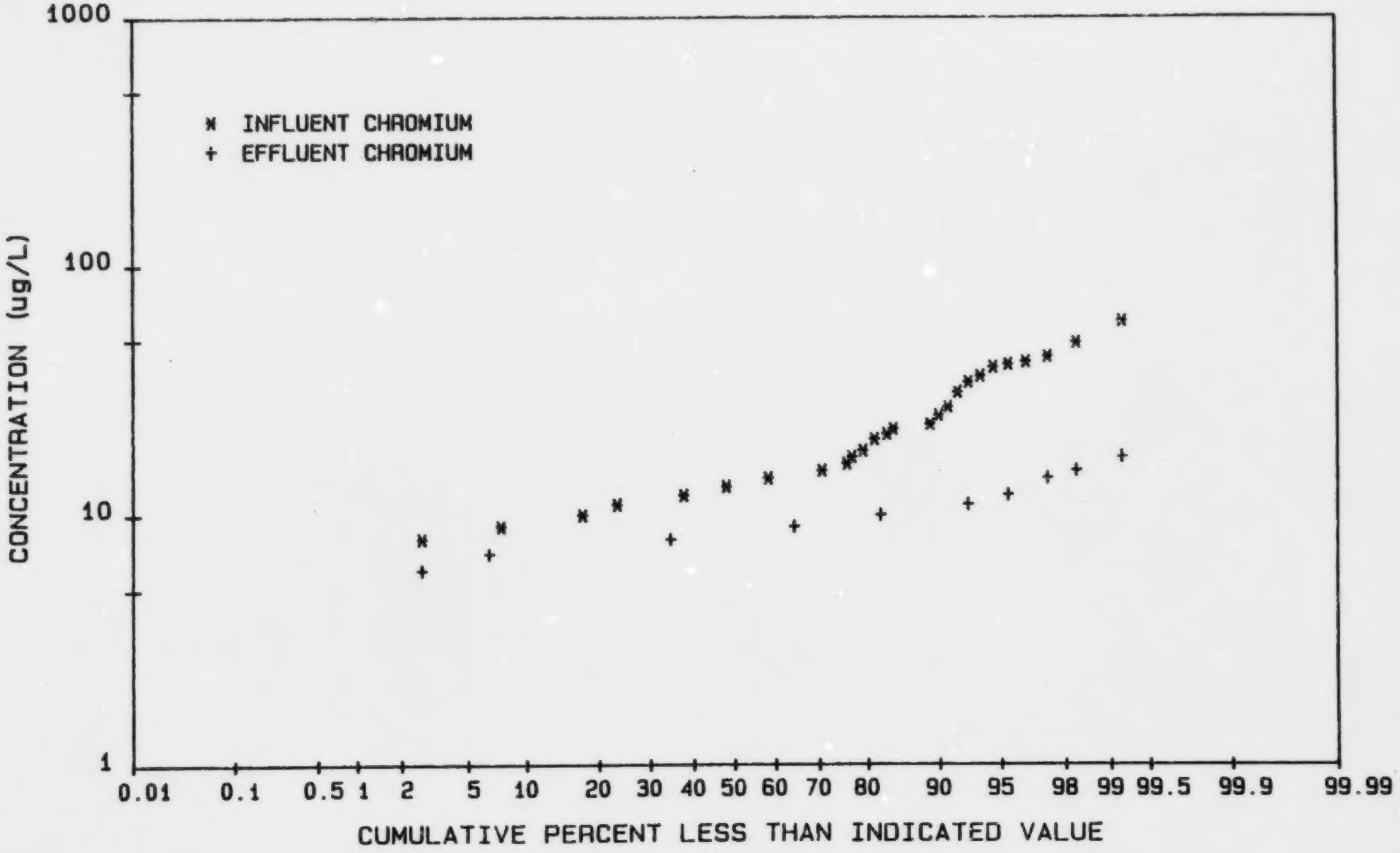


FIGURE 56 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHROMIUM CONCENTRATION AT WELLAND STP

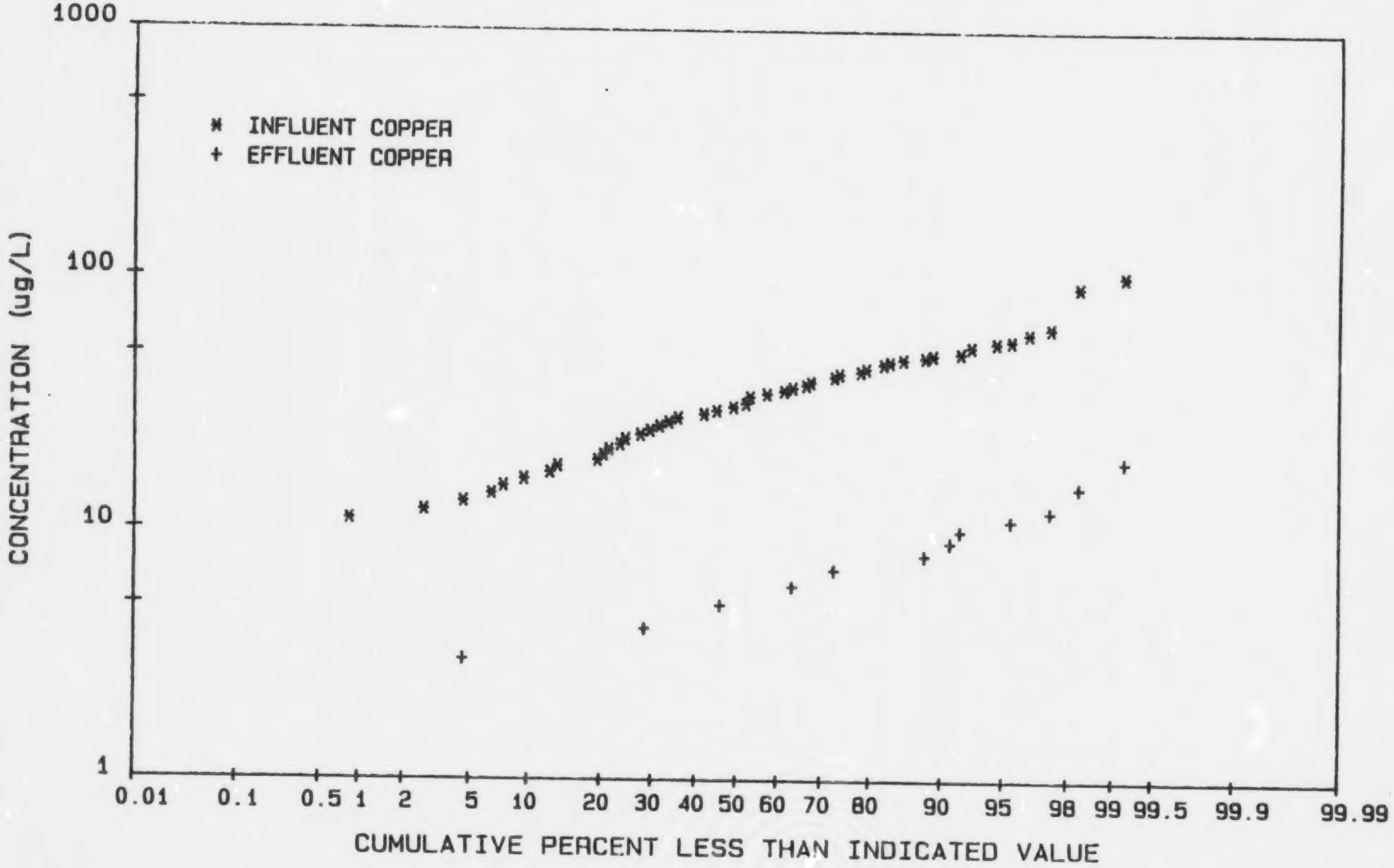


FIGURE 57 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT COPPER CONCENTRATION AT WELLAND STP

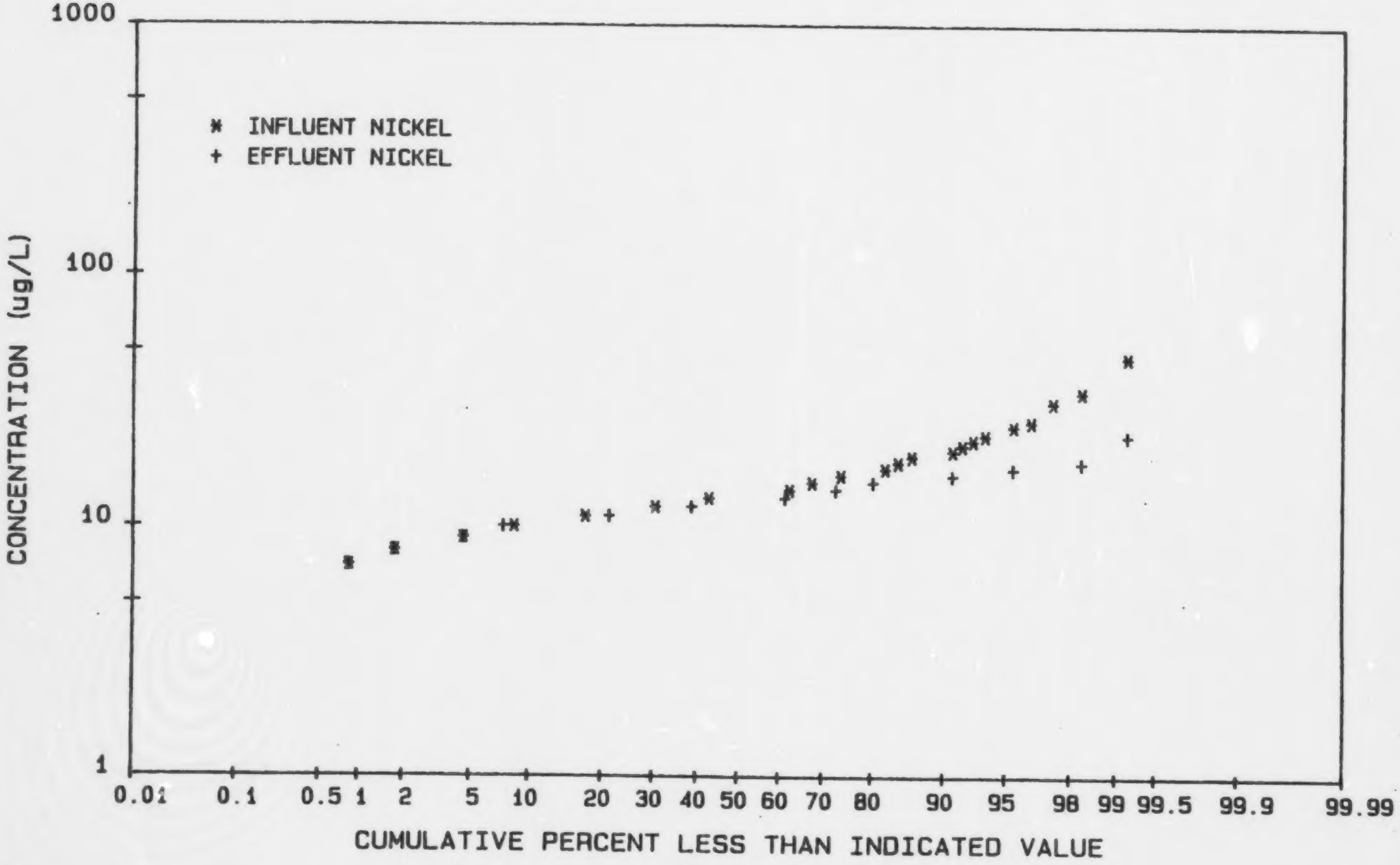


FIGURE 58 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT NICKEL CONCENTRATION AT WELLAND STP

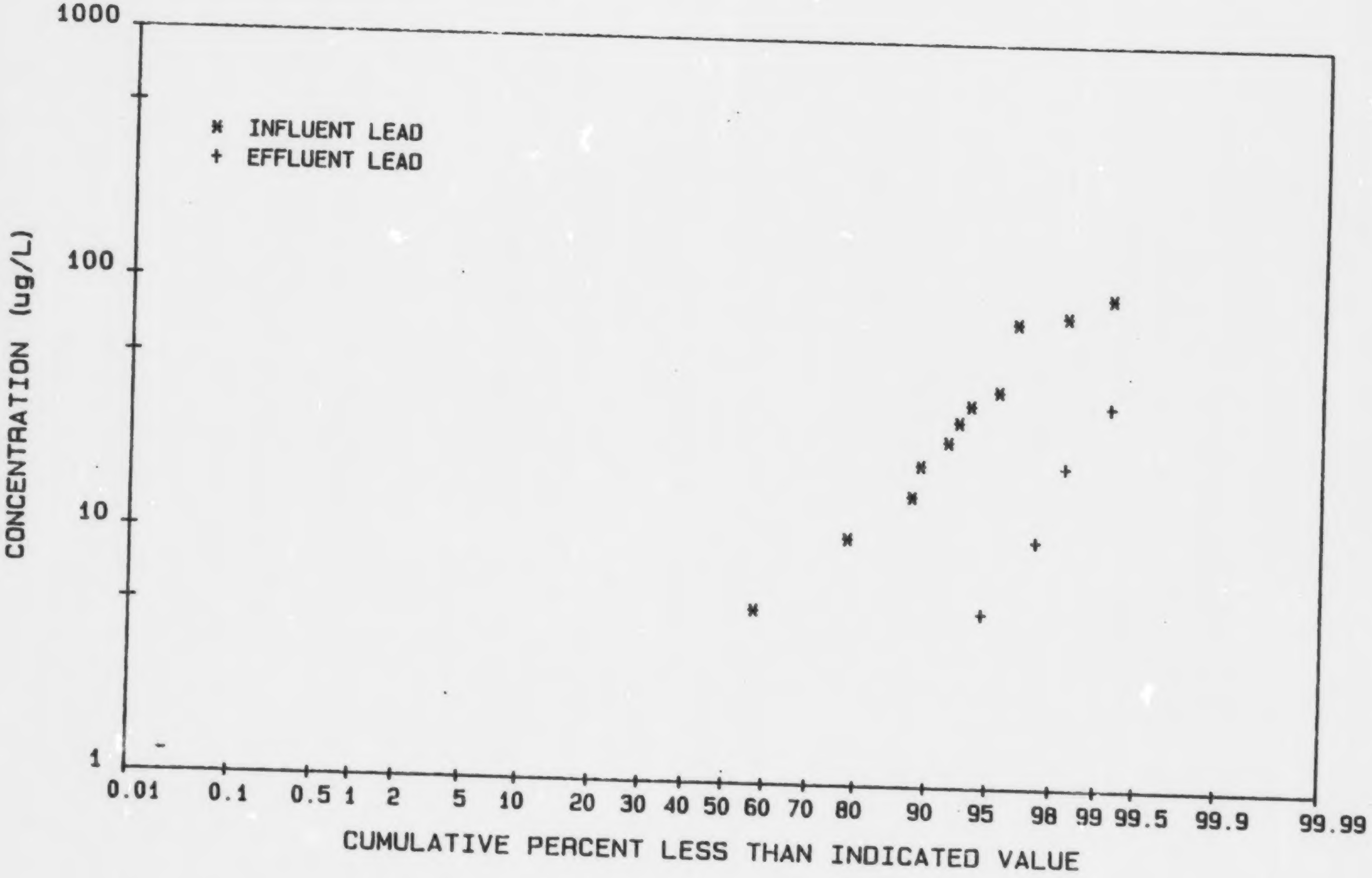


FIGURE 59 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT LEAD CONCENTRATION AT WELLAND STP

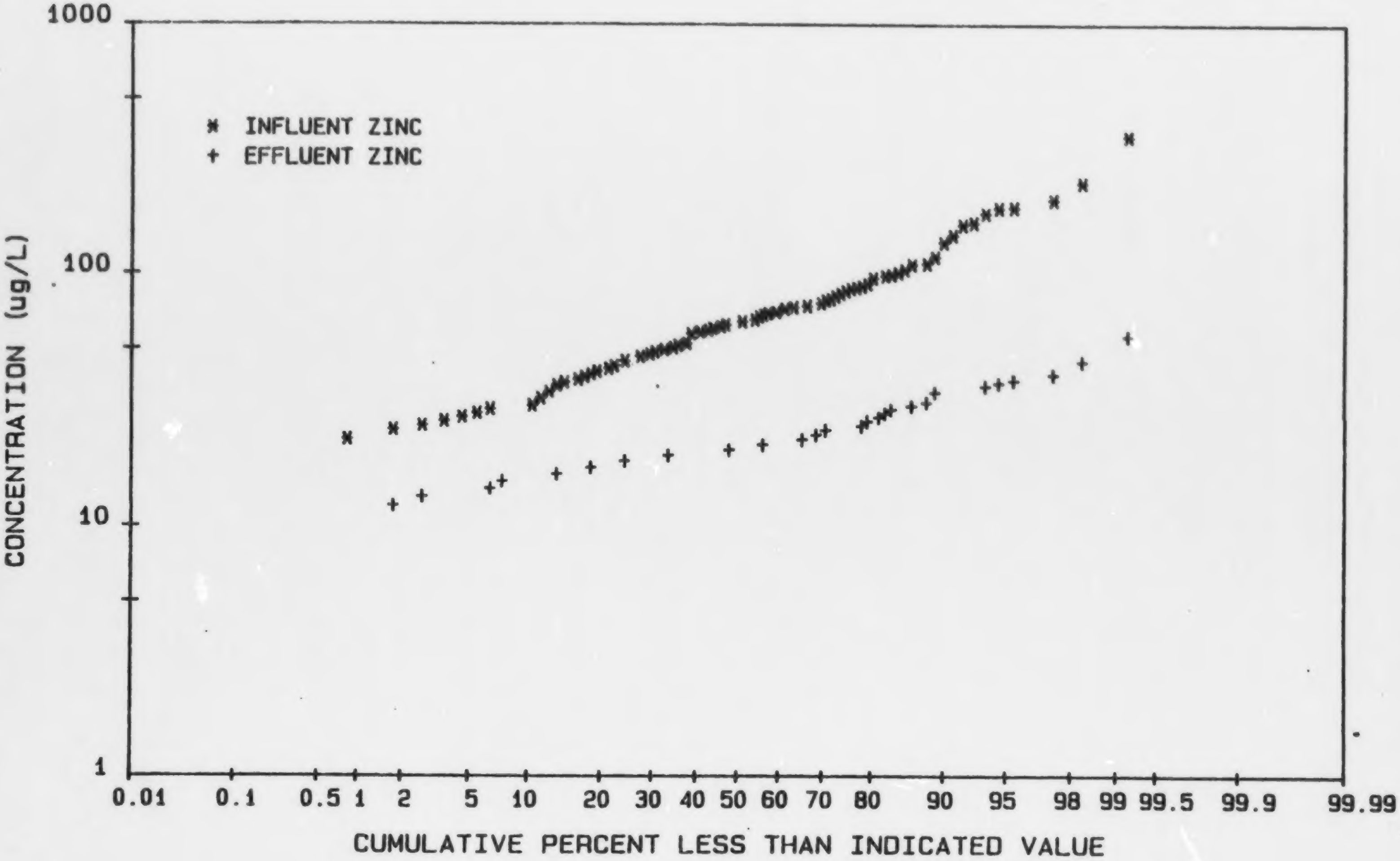


FIGURE 60 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT ZINC CONCENTRATION AT WELLAND STP

Table 35
METAL CONTAMINANT DATA FOR WELLAND STP

	Influent**					Effluent**				
Parameter*	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Cadmium	2.7	2.9	1.2	41.4	5.4	2.4	2.6	0.9	34.6	4.3
Chromium	14.9	16.5	9.2	55.8	39.0	9.1	9.3	1.7	18.3	12.4
Copper	30.9	34.1	15.5	45.5	57.2	5.8	6.3	2.6	41.3	12.0
Nickel	14.4	15.1	5.5	36.4	25.1	13.0	13.3	2.5	18.8	18.0
Lead	8.3	12.2	16.2	133.	44.7	5.3	5.6	3.4	60.7	8.8
Zinc	64.9	76.2	50.6	66.4	181.	21.9	22.9	7.6	33.2	38.2

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*All concentrations reported in µg/L. RSD reported in %.

**Based on 99 samples.

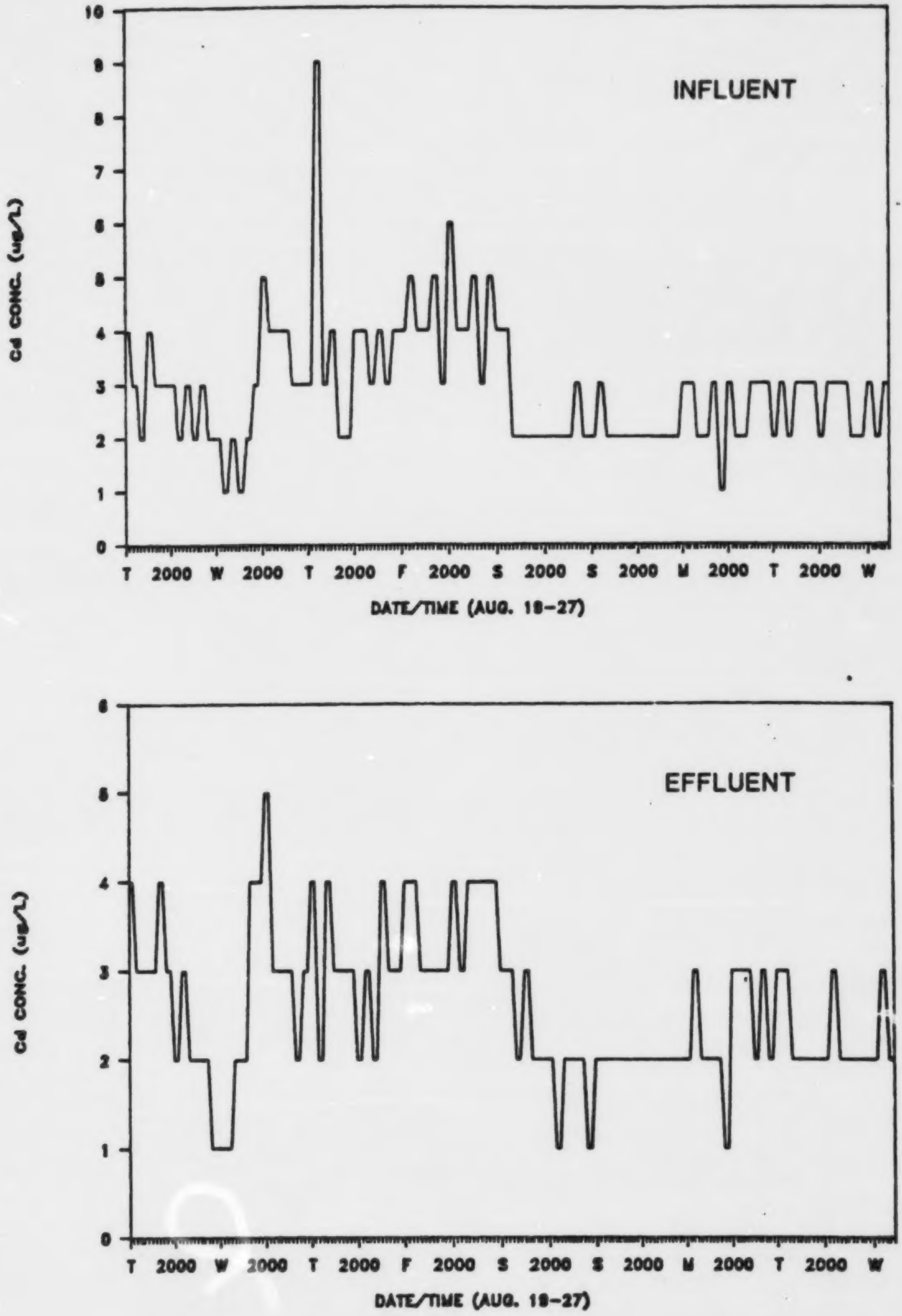


FIGURE 61: CHRONOLOGY OF INFLUENT AND EFFLUENT Cd AT WELLAND WPCP

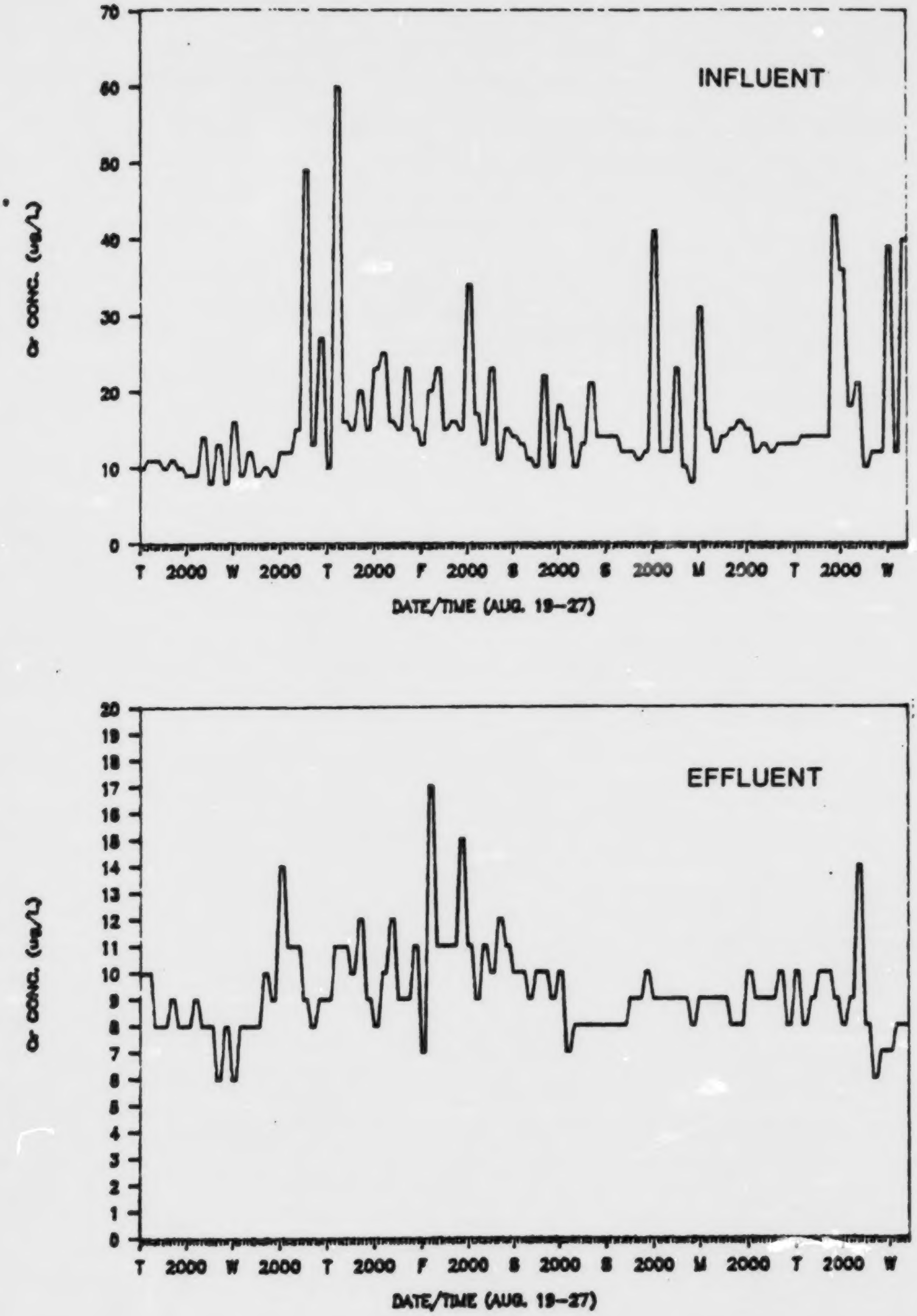


FIGURE 62: CHRONOLOGY OF INFLUENT AND EFFLUENT Cr AT WELLAND WPCP

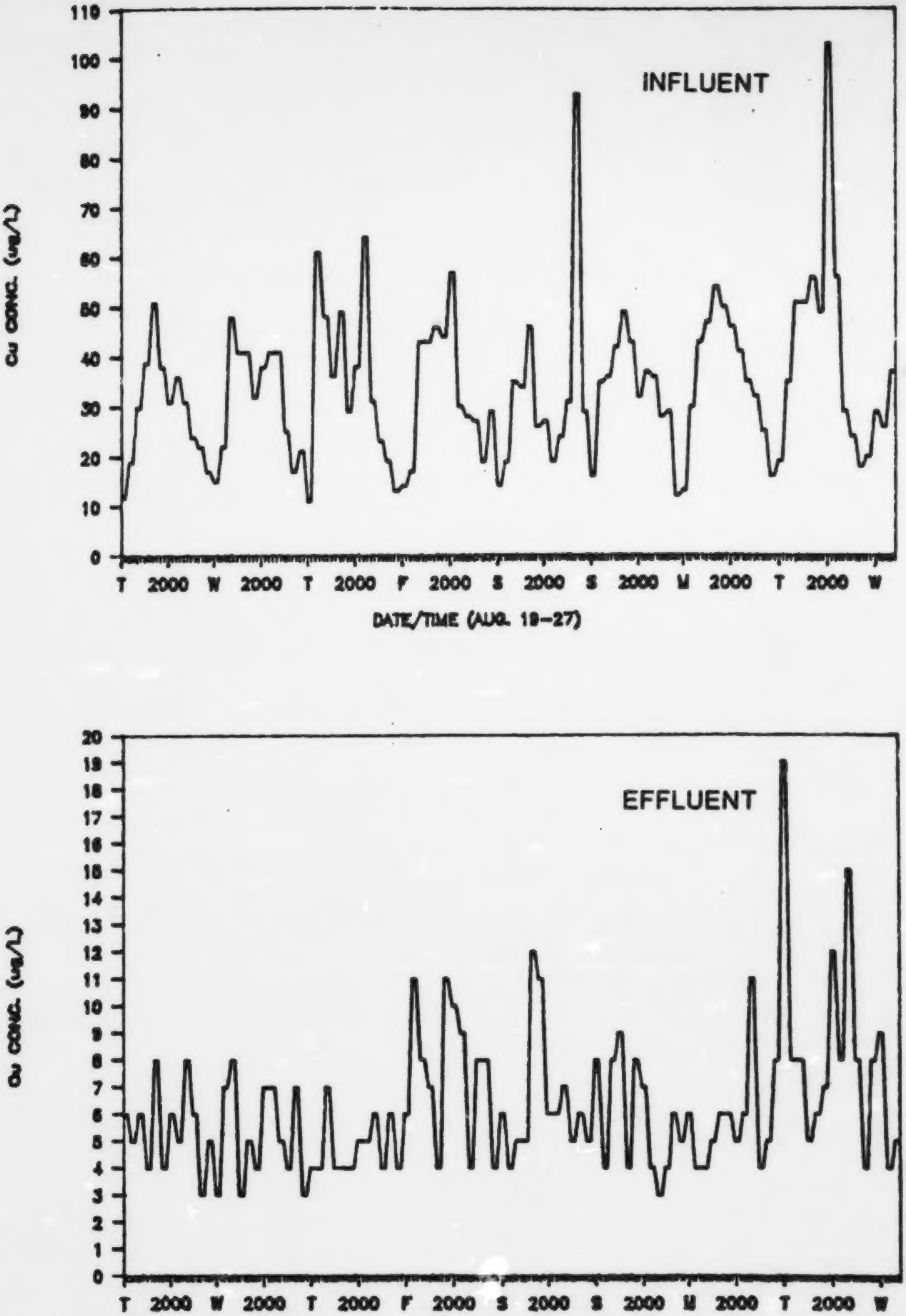


FIGURE 63: CHRONOLOGY OF INFLUENT AND EFFLUENT Cu AT WELLAND WPCP

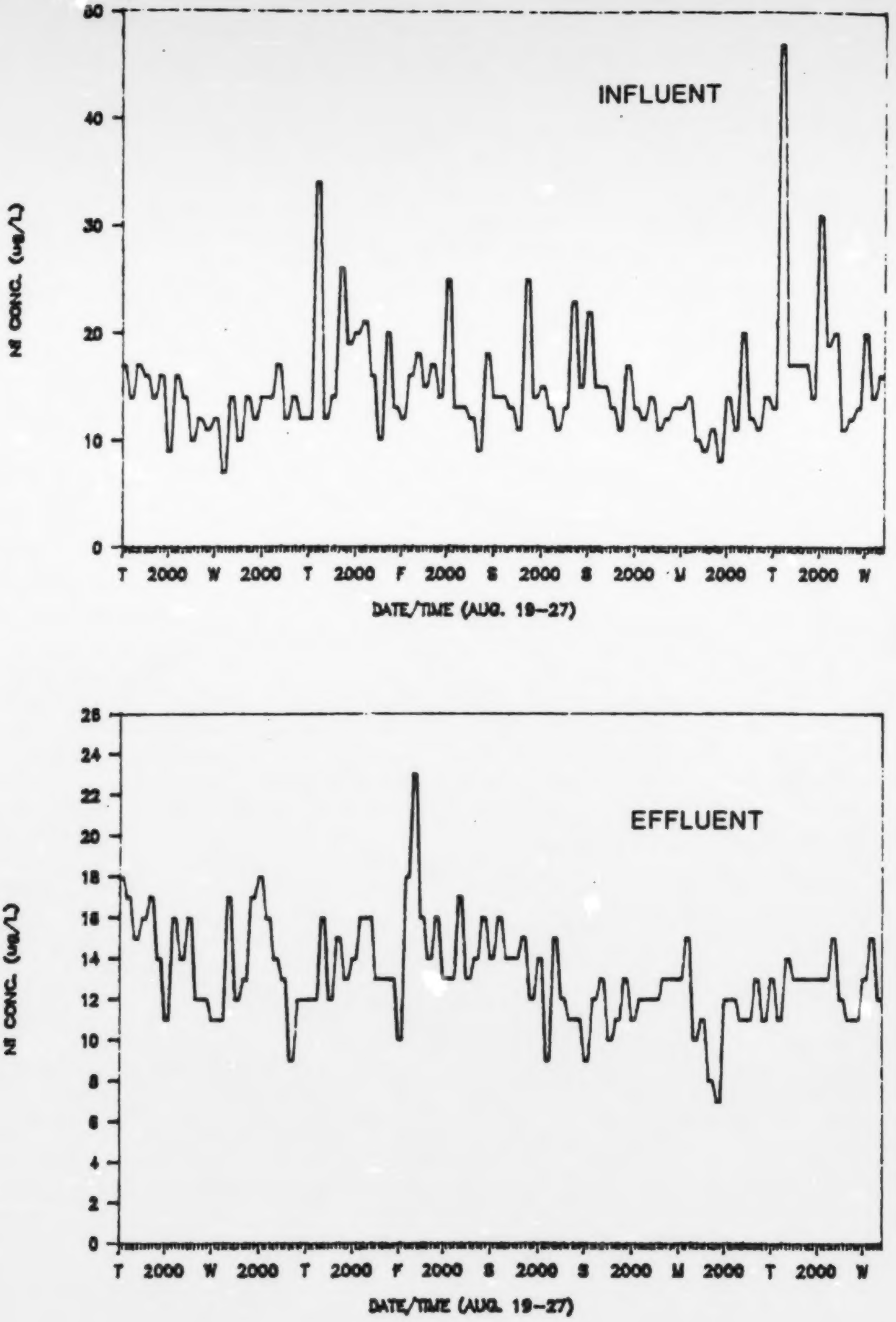
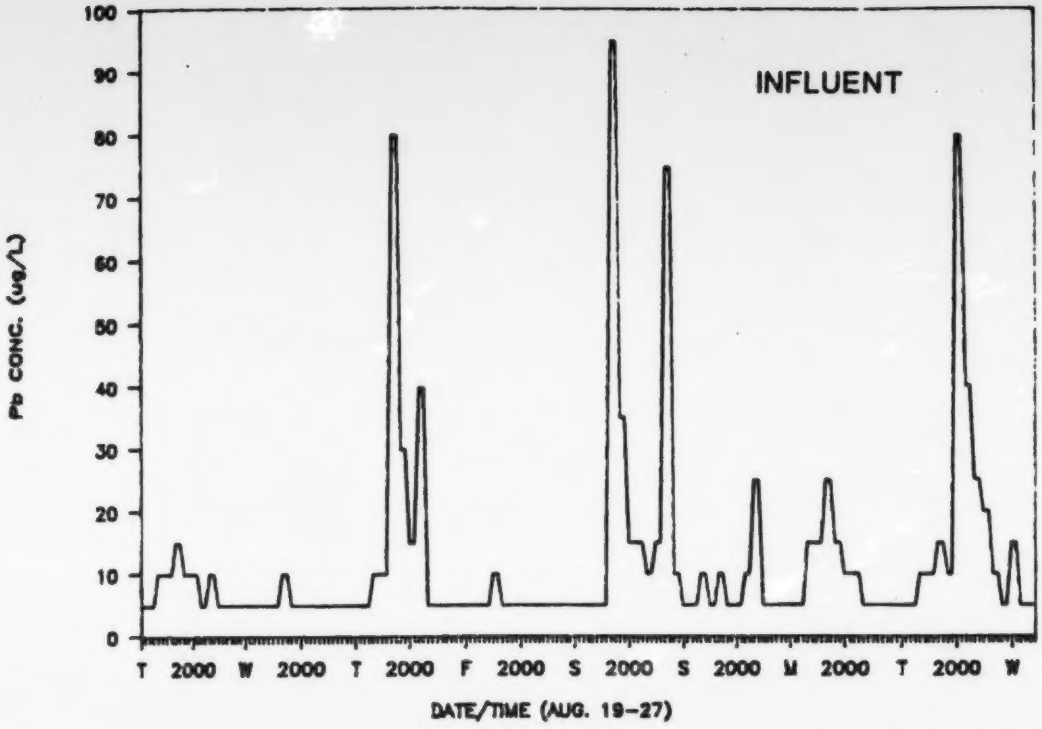


FIGURE 64: CHRONOLOGY OF INFLUENT AND EFFLUENT Ni AT WELLAND WPCP



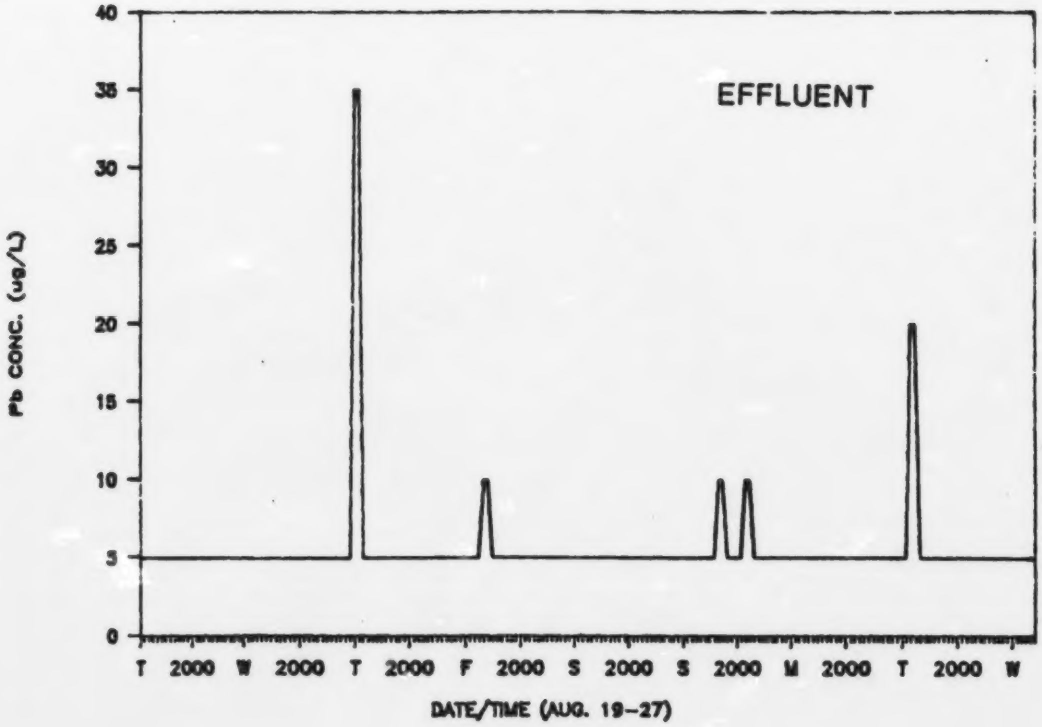
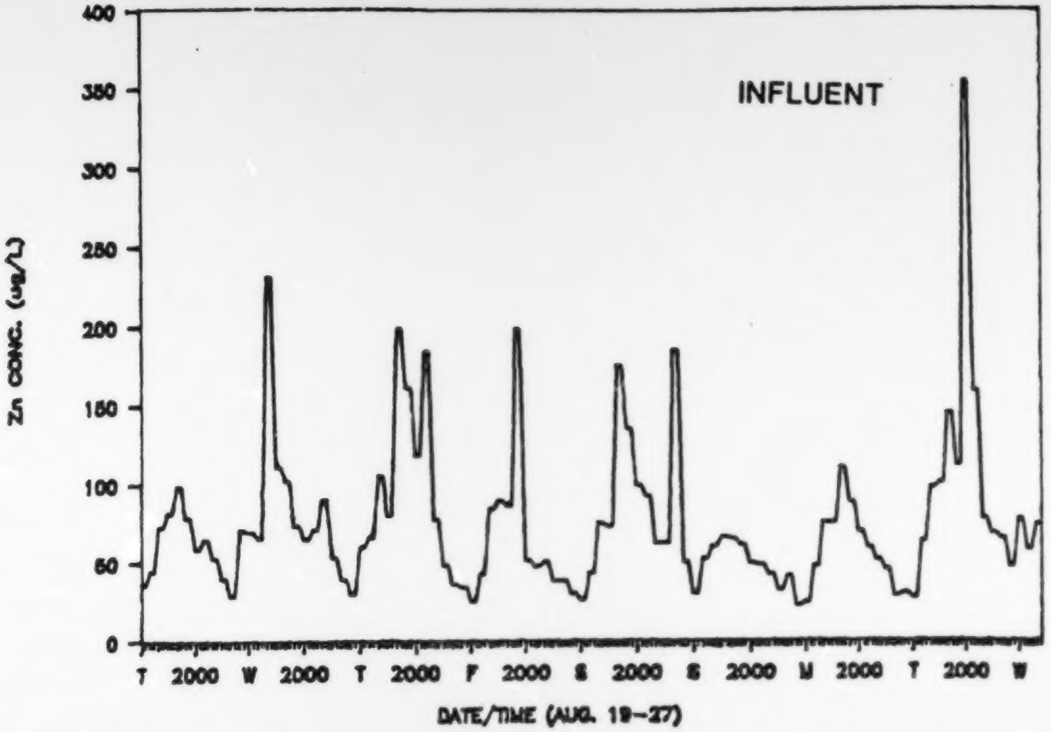


FIGURE 65: CHRONOLOGY OF INFLUENT AND EFFLUENT Pb AT WELLAND WPCP



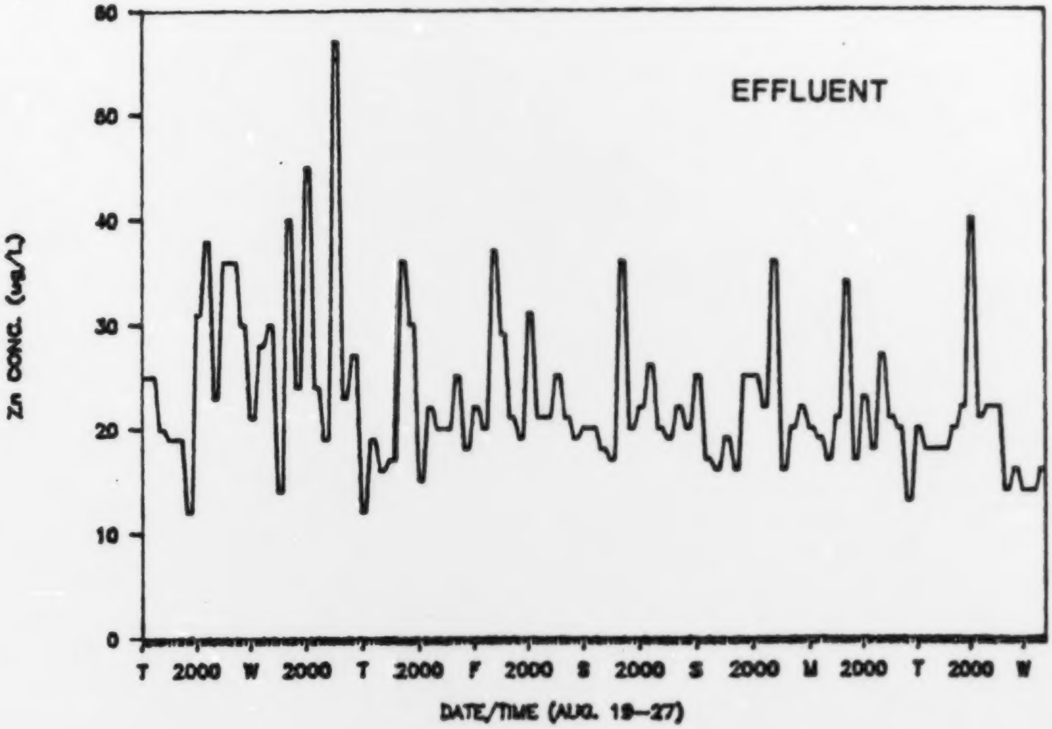


FIGURE 66: CHRONOLOGY OF INFLUENT AND EFFLUENT Zn AT WELLAND WPCP

in the plant effluent. As with chromium and cadmium, the lack of resolution of the analytical method at the low effluent concentrations may have contributed to the lack of identifiable effluent response. Raw sewage nickel concentrations also exhibited a random variability with no significant diurnal pattern (Figure 64). Identifying an effluent concentration trend was again impeded by the lack of analytical resolution at the low effluent levels at the Welland STP.

Influent lead concentrations (Figure 65) were below the detection limit (5 μg/L) more than 50 percent of the time and effluent concentrations were less than the detection limit more than 90 percent of the time. Thus, there were insufficient data in either chronological sequence to draw conclusions regarding trends and correlations.

Influent zinc concentrations showed a significant diurnal trend (Figure 66), but this trend was not reproduced in the effluent concentration sequence. There was no significant correlation between the influent and effluent concentrations.

Average removal efficiencies for the six metals discussed above are summarized in Table 36.

Table 36
REMOVAL OF HEAVY METALS AT WELLAND STP

Metal	Removal (Percent) Based on Arithmetic Mean	Removal (Percent) Based on Geometric Mean
Cadmium	10.3	11.1
Chromium	43.6	38.9
Copper	81.5	81.2
Nickel	11.9	9.7
Lead	54.1	35.1
Zinc	69.9	66.3

The trend in the removal data is similar to that seen at the Waterloo STP and in other studies(4), with copper demonstrating the highest degree of removal and nickel showing low removal efficiency.

Cadmium removal was low due to the low influent and effluent concentrations measured. Lead, zinc and chromium removal performance was very similar to that measured at the Waterloo STP.

4.2.3 Trace Organics

4.2.3.1 Phenolics

A probability distribution of influent and effluent total phenolics concentrations at the Welland STP is presented in Figure 67. Phenol removal efficiency was 79 percent. Concentration was reduced from an influent geometric mean of 9.7 µg/L (arithmetic mean 12.4 µg/L; RSD = 66.9 percent) to an effluent geometric mean of 2.0 µg/L (arithmetic mean 2.6 µg/L; RSD = 80.8 percent). The chronological data trend is illustrated in Figure 68. No statistically significant diurnal trend was apparent in the data. Effluent levels were at or below the detection limit (1 µg/L) approximately 36 percent of the time.

4.2.3.2 Volatile Organics

Table 37 summarizes the frequency of detection (FOD) of selected chlorinated and non-chlorinated organics in raw sewages and effluents from the Welland STP. Dichloromethane was quantified at least at trace levels in virtually all influent and effluent samples, as was the case during the Waterloo sampling. At Welland, 1,1,1-trichloroethane was present in 74 percent of influent and effluent samples at concentrations greater than the MDL and in at least 85 percent of all samples at greater than trace levels. Similar concentrations of 1,1,1-trichloroethane were detected in travel blanks (2.0 µg/L). Therefore, the consistent presence of dichloromethane and 1,1,1-trichloroethane in most samples is considered to represent a contamination problem.

Of the remaining organics, only toluene (68 percent FOD), chloroform (90 percent FOD) and 1,4-dichlorobenzene (96 percent FOD) were quantifiable at more than the MDL in more than 50 percent of raw sewage samples. These compounds were also identified frequently in raw sewage samples at the Waterloo STP. Trichloroethylene (37 percent FOD), p & m-xylene (43 percent) and o-xylene (48 percent FOD) were the only other compounds present at more than the MDL in more

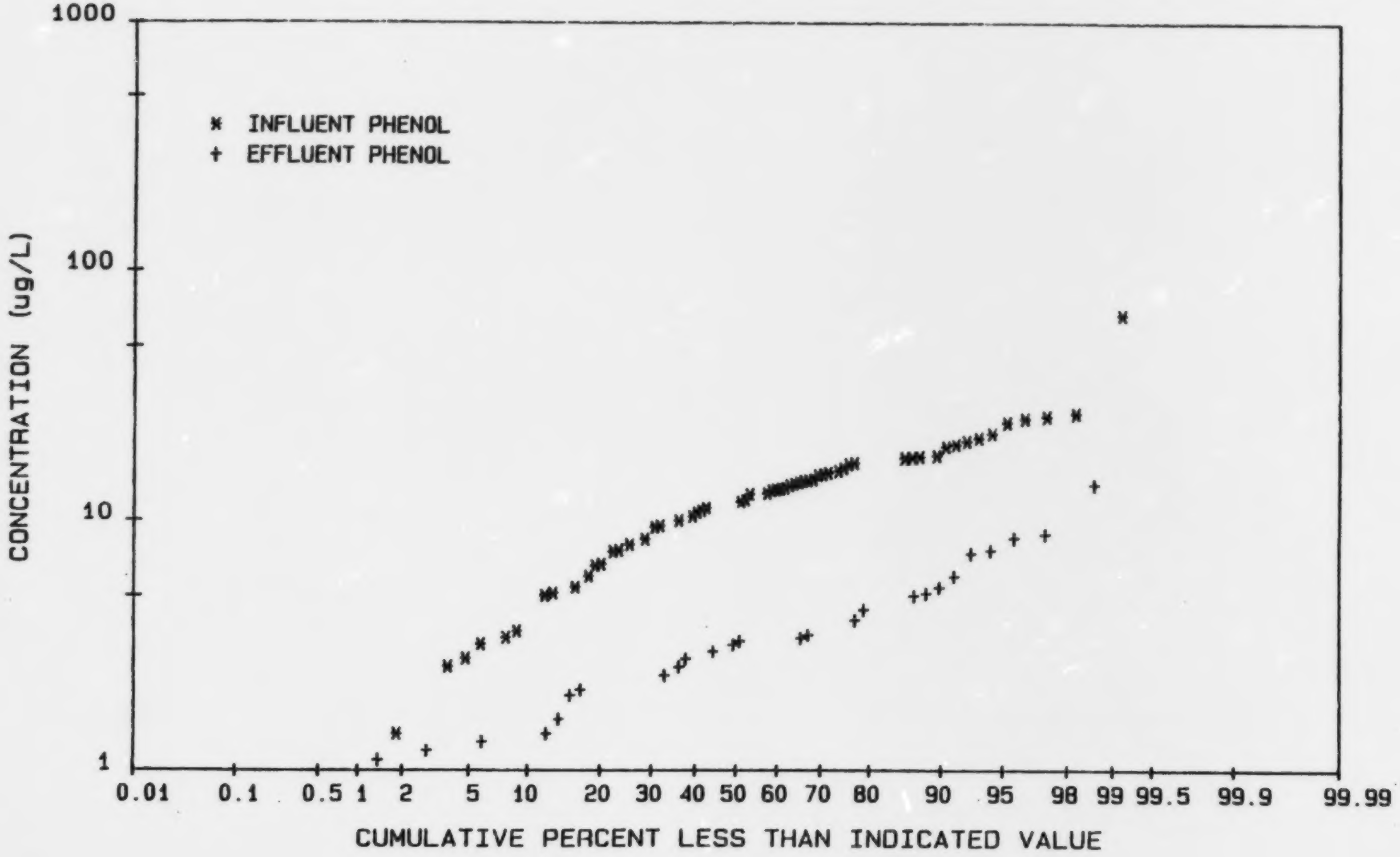


FIGURE 67 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOTAL PHENOL CONCENTRATION AT WELLAND STP

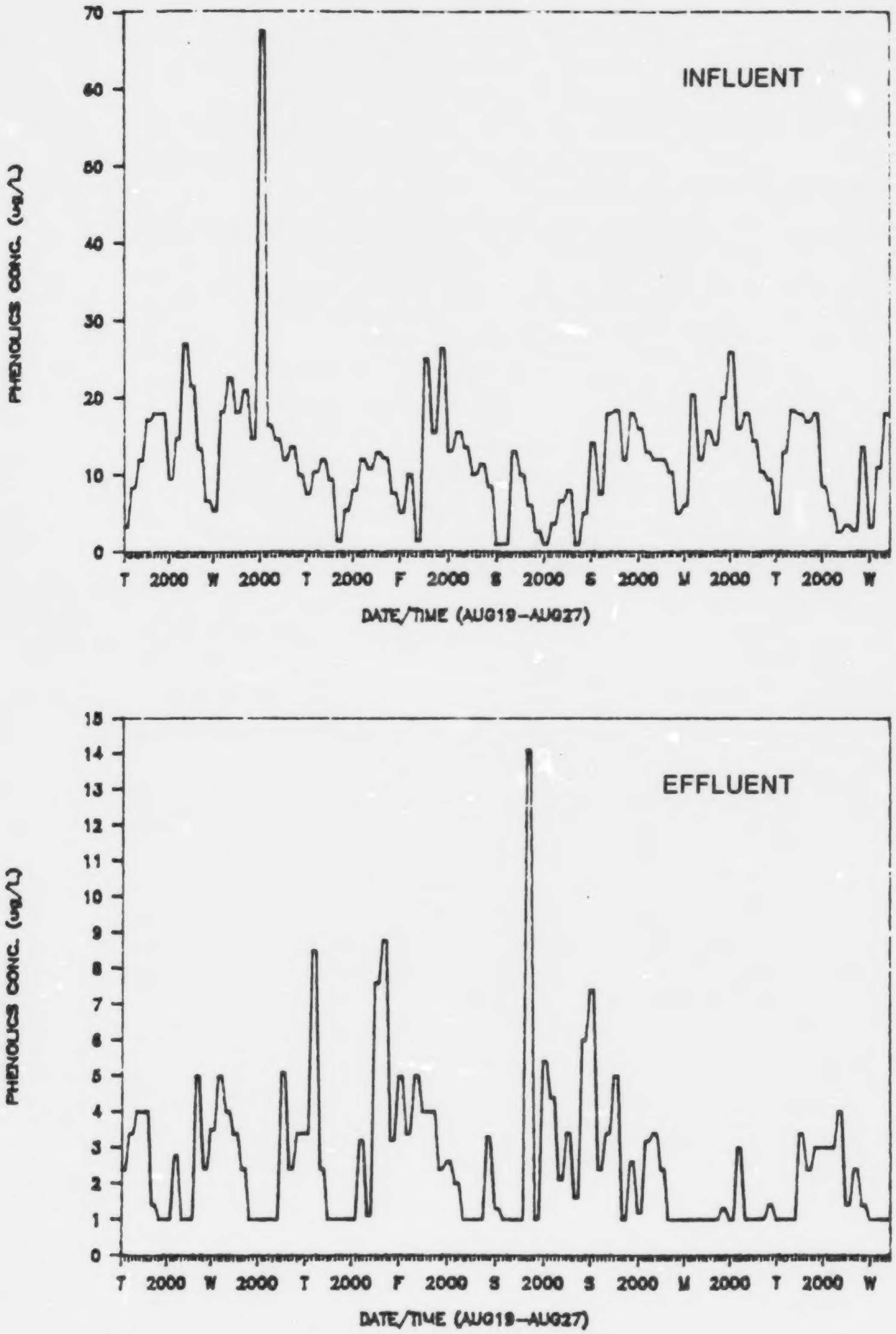


FIGURE 68: CHRONOLOGY OF INFLUENT AND EFFLUENT TOTAL PHENOL AT WELLAND WPCP

Table 37
FREQUENCY OF DETECTION OF VOLATILE ORGANIC CONTAMINANTS AT WELLAND STP

Compound	MDL (μg/L)	Frequency of Detection* (%)	
		Influent	Effluent
Dichloromethane	1.0	98	87
Chloroform	1.0	90	8
1,2-dichloroethylene	1.0	0	0
1,1,1-trichloroethane	1.0	74	74
Benzene	0.5	9	1
Carbon tetrachloride	1.0	0	0
Bromodichloromethane	1.0	1	0
Trichloroethylene	1.0	37	0
1,1,2-trichloroethane	1.0	0	0
Toluene	0.5	68	1
Dibromochloromethane	1.0	0	0
Tetrachloroethylene	1.0	8	0
Chlorobenzene	0.5	4	1
Ethylbenzene	0.5	10	0
p & m-xylene	0.5	43	9
Bromoform	1.0	0	0
o-xylene	0.5	48	1
1,2,2-tetrachloroethane	1.0	0	0
1,3-dichlorobenzene	1.0	0	0
1,4-dichlorobenzene	1.0	96	8
1,2-dichlorobenzene	1.0	4	0

---

*At concentrations above the MDL.

than twenty percent of raw sewage samples. No volatile organics, except dichloromethane and 1,1,1-trichloroethane as previously discussed, were identified in more than 10 percent of effluent samples at greater than the MDL.

Probability distributions for compounds found with a high degree of prevalence in the raw sewage are presented in Figures 69 (chloroform), 70 (trichloroethylene), 71 (1,4-dichlorobenzene), 72 (toluene) and 73 (p & m-xylene). Key statistics describing these distributions are summarized in Table 38. Chronological plots for these compounds are shown in Figures 74 to 78. In all cases, little interpretation of effluent data is possible because of the low FOD of these organic compounds. Raw sewage data show considerably more variability but no measurable response in the effluent was noted. Calculated removal efficiencies, are presented in Table 39. Because of the low influent concentrations and the near MDL concentrations in the effluent, reported removal efficiencies at Welland were generally lower than those reported at Waterloo.

Table 39
REMOVAL OF VOLATILE ORGANICS AT WELLAND STP

	Removal (percent) Based On	
Compound	Arithmetic Mean	Geometric Mean
Chloroform	83	79
Trichloroethylene	>23	--
1,4-dichlorobenzene	60	60
Toluene	>58	>38
p, m-xylene	69	50

4.2.3.3 PAHs

As noted in Section 2.3.3, only ten influent and effluent samples were analyzed for PAHs from the Welland plant. Table 40 summarizes the results of these analyses. In general, PAHs which were detected were quantified with a greater frequency at the Welland STP than at the Waterloo STP. However, concentrations in influents and effluents were typically near MDL levels.

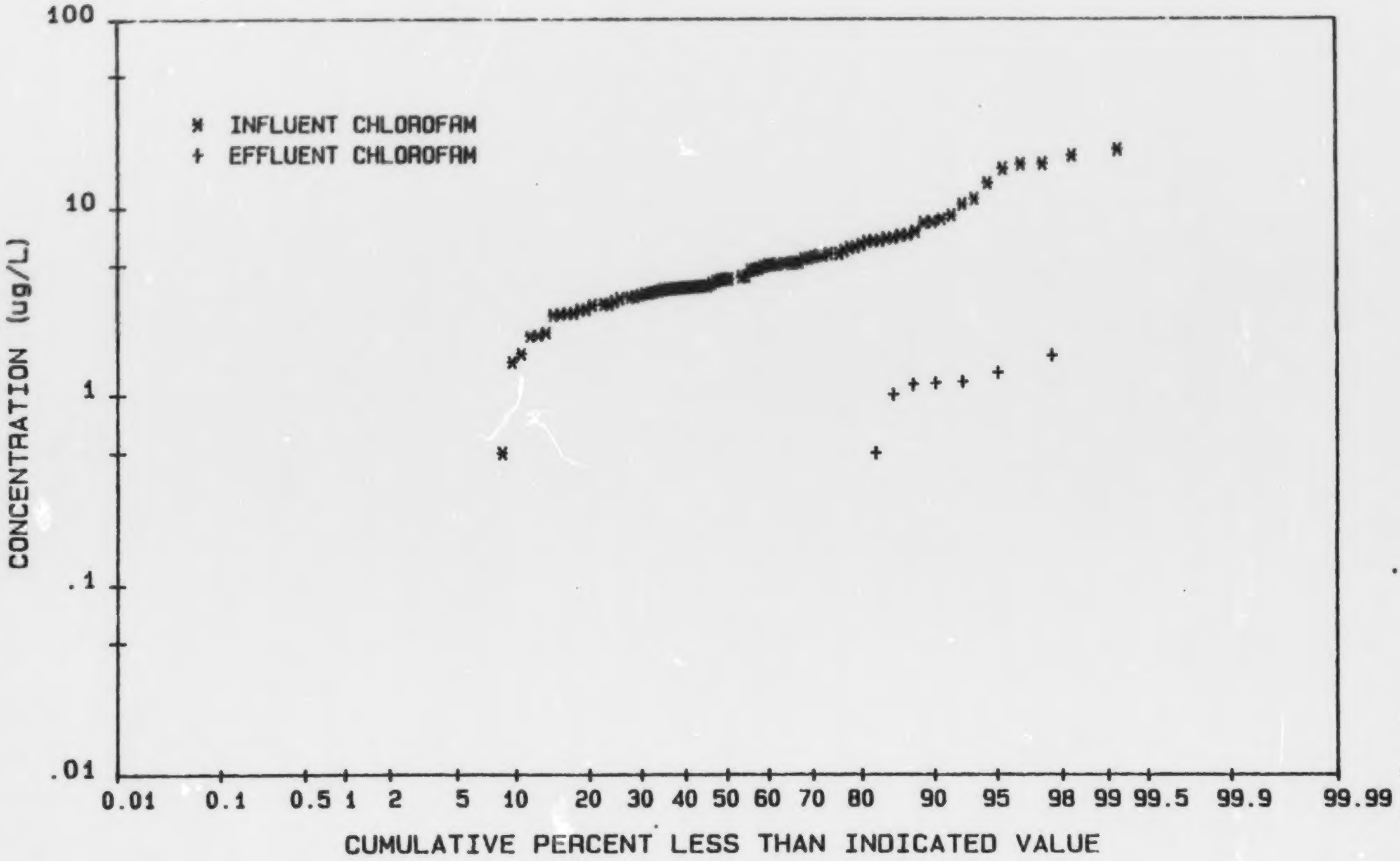


FIGURE 69: PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHLOROFORM CONCENTRATION AT WELLAND STP

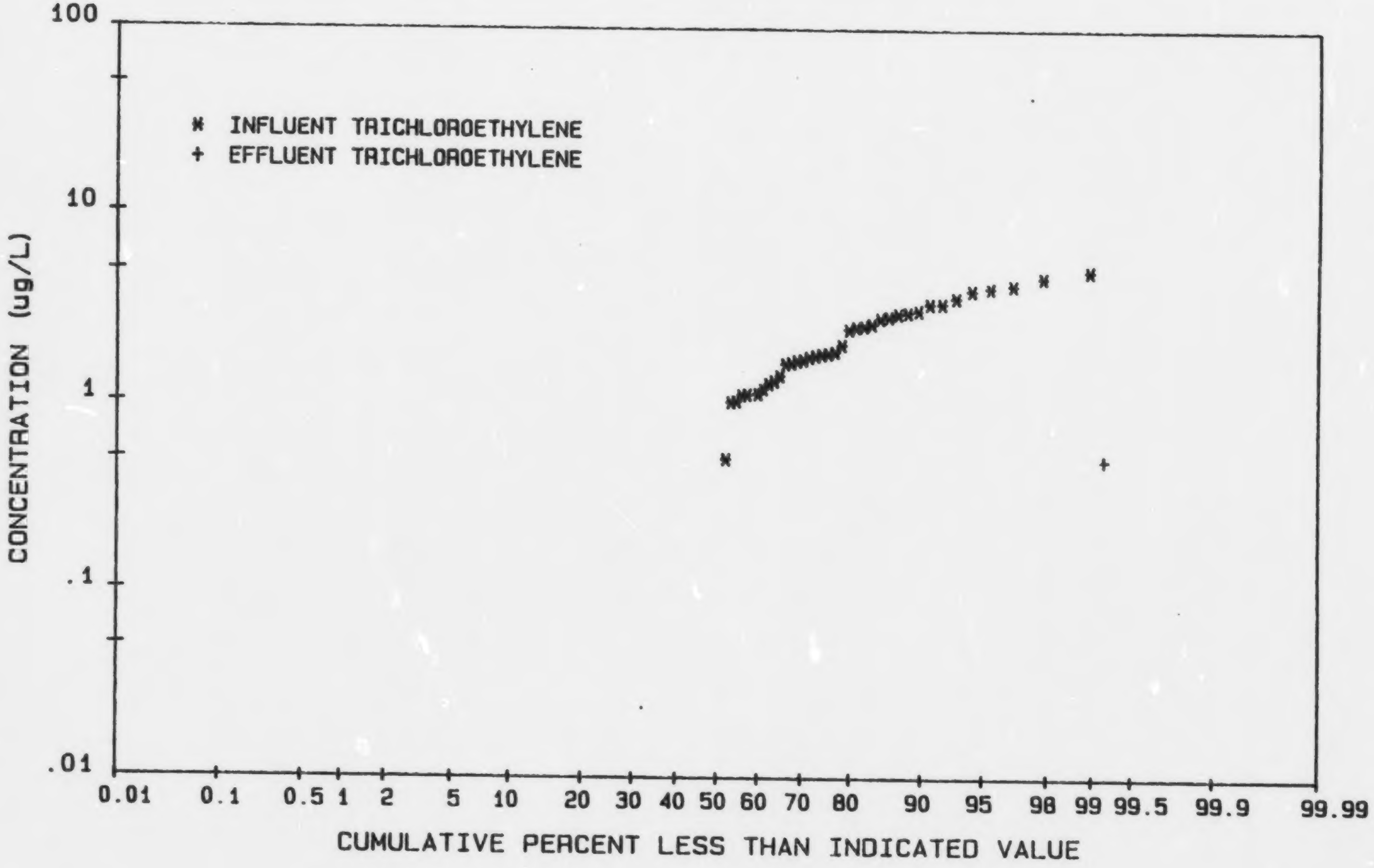


FIGURE 70 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE CONCENTRATION AT WELLAND STP

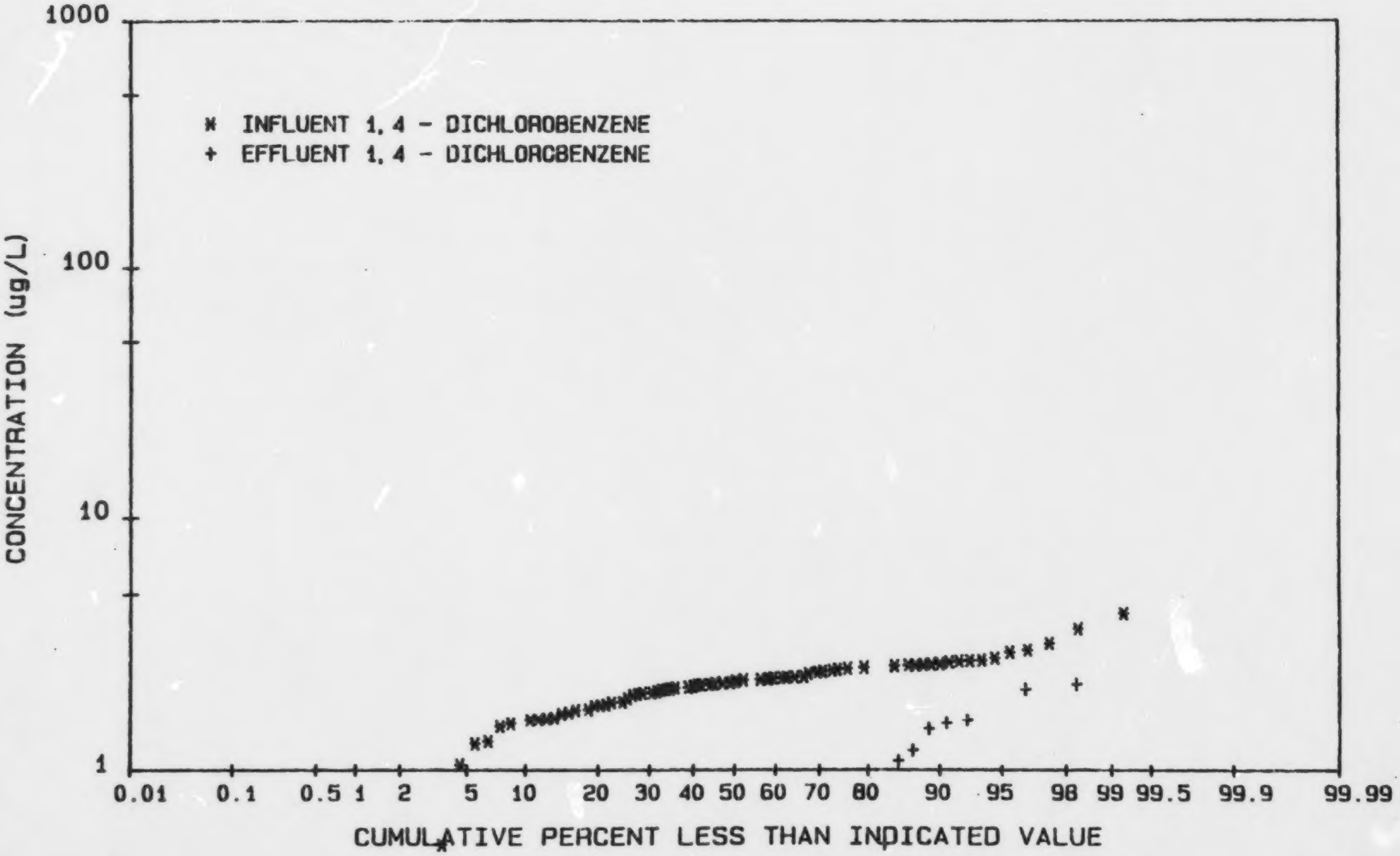


FIGURE 71 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT 1, 4 - DICHLOROBENZENE CONCENTRATION AT WELLAND STP

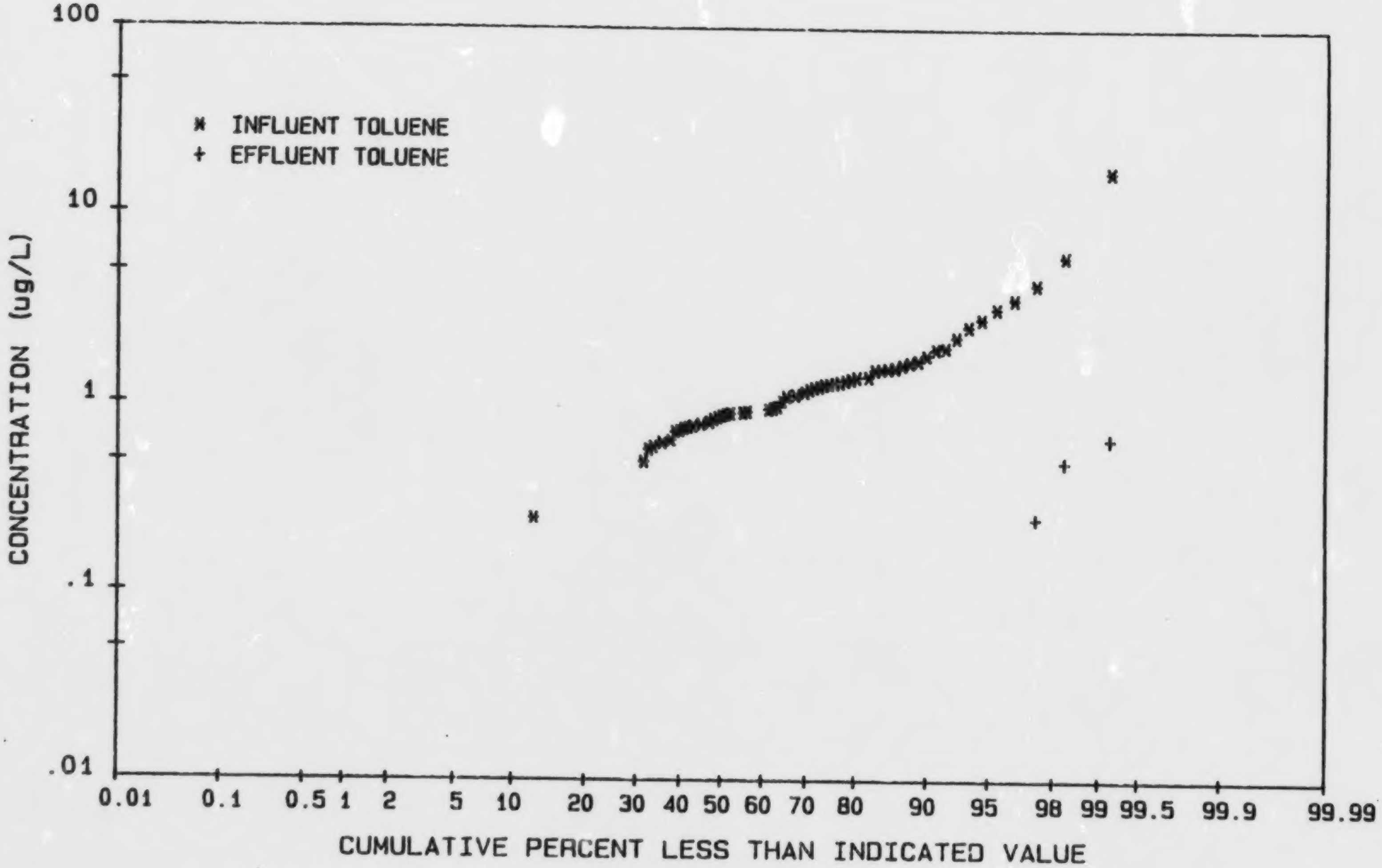


FIGURE 72 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOLUENE CONCENTRATION AT WELLAND STP

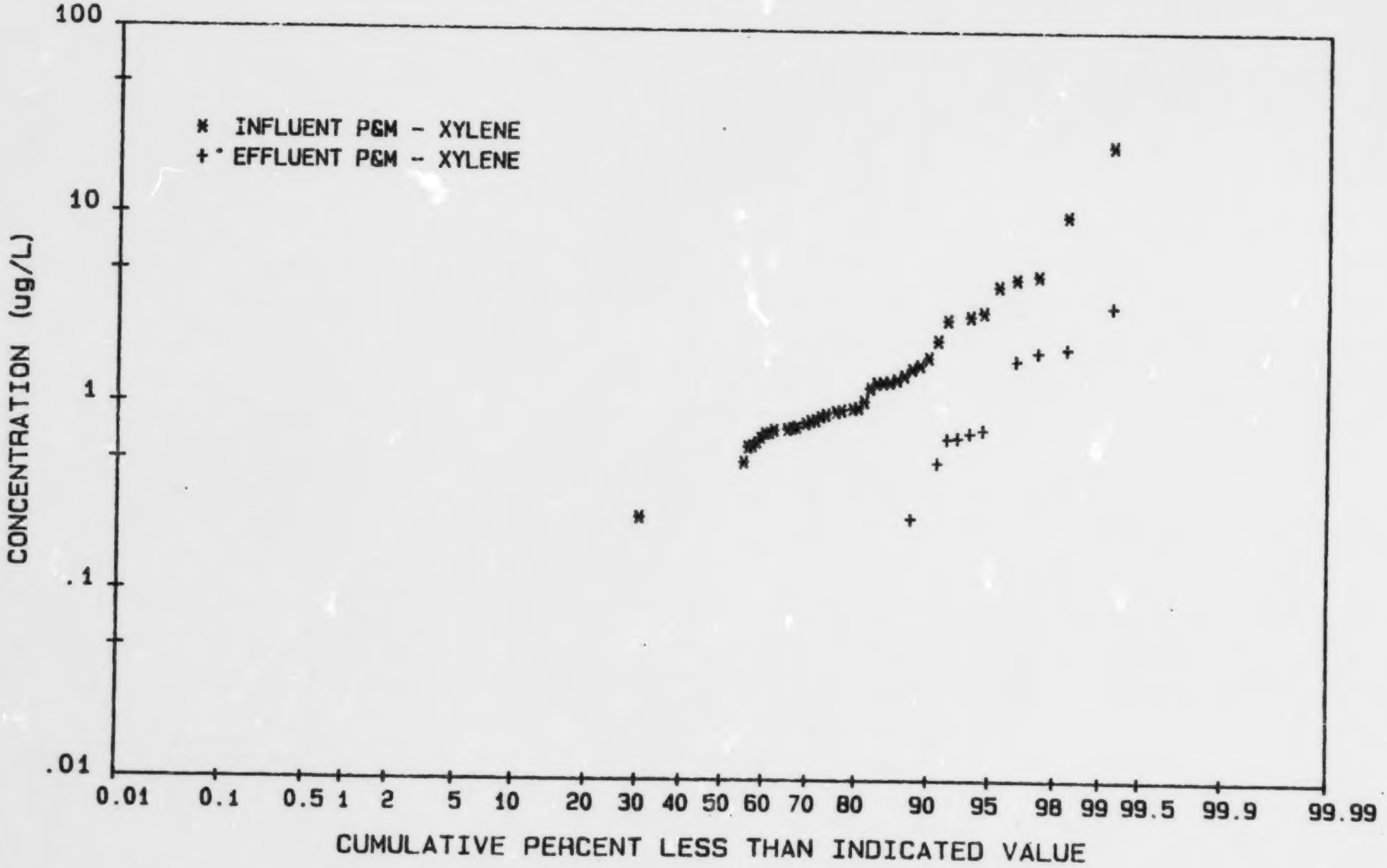


FIGURE 73 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT P&M - XYLENE CONCENTRATION AT WELLAND STP

Table 38
VOLATILE ORGANIC CONCENTRATION DATA FOR WELLAND STP

Compound*	Influent**					Effluent**				
	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Chloroform	3.9	5.1	3.7	72.5	15.1	0.8	0.9	0.3	33.3	1.1
Trichloroethylene	1.0	1.3	1.1	84.6	4.0	<1.0	<1.0	-	-	<1.0
1,4-dichlorobenzene	2.1	2.2	0.6	27.3	2.8	0.8	0.9	0.4	44.4	1.5
Toluene	0.8	1.2	1.8	150.	3.2	<0.5	<0.5	-	-	<0.5
p&m-xylene	0.6	1.2	2.7	225.	3.3	0.3	0.4	0.5	125.	1.0

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*All concentrations reported in μg/L. RSD reported in %.
**Based on 99 samples.

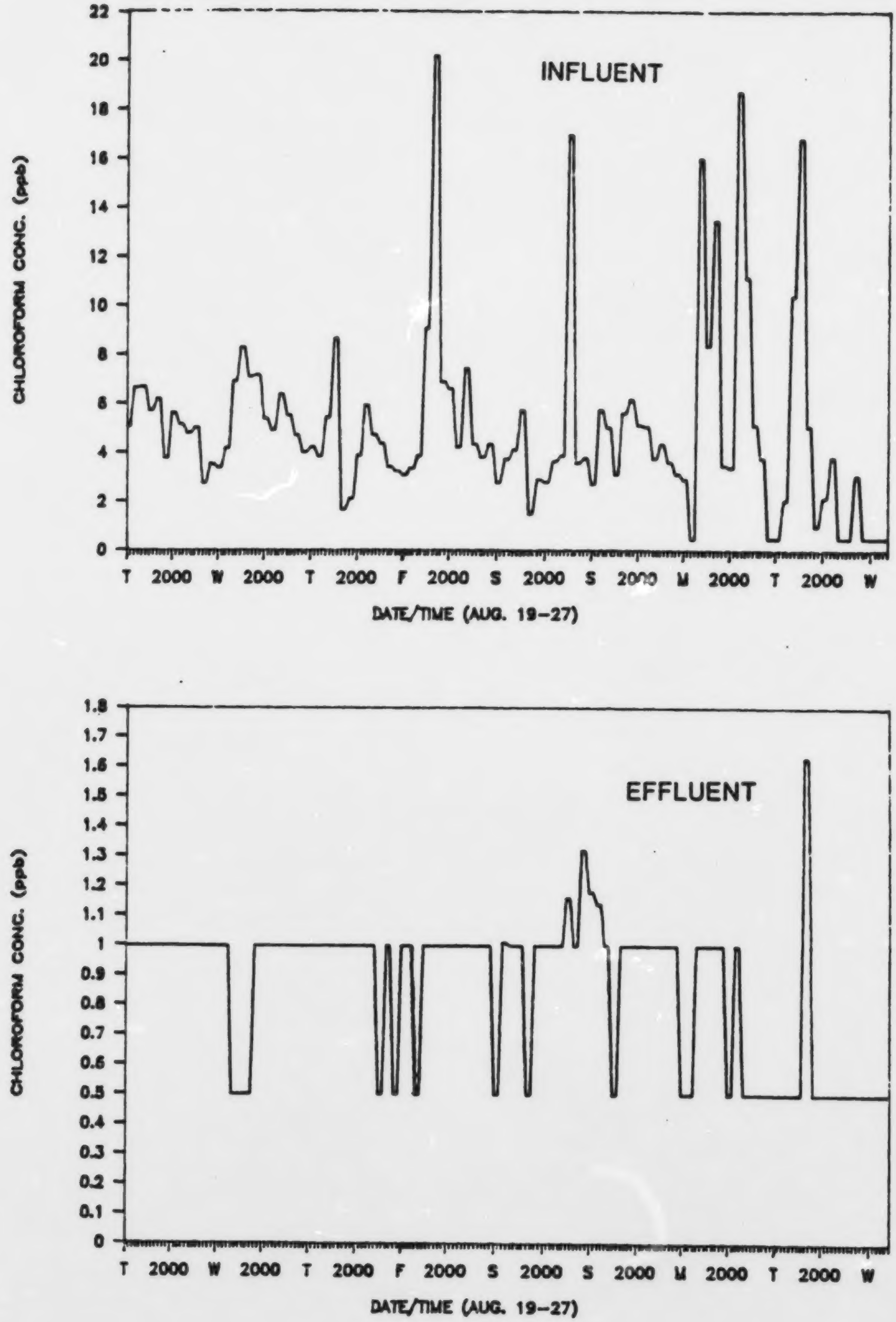


FIGURE 74: CHRONOLOGY OF INFLUENT AND EFFLUENT CHLOROFORM AT WELLAND WPCP

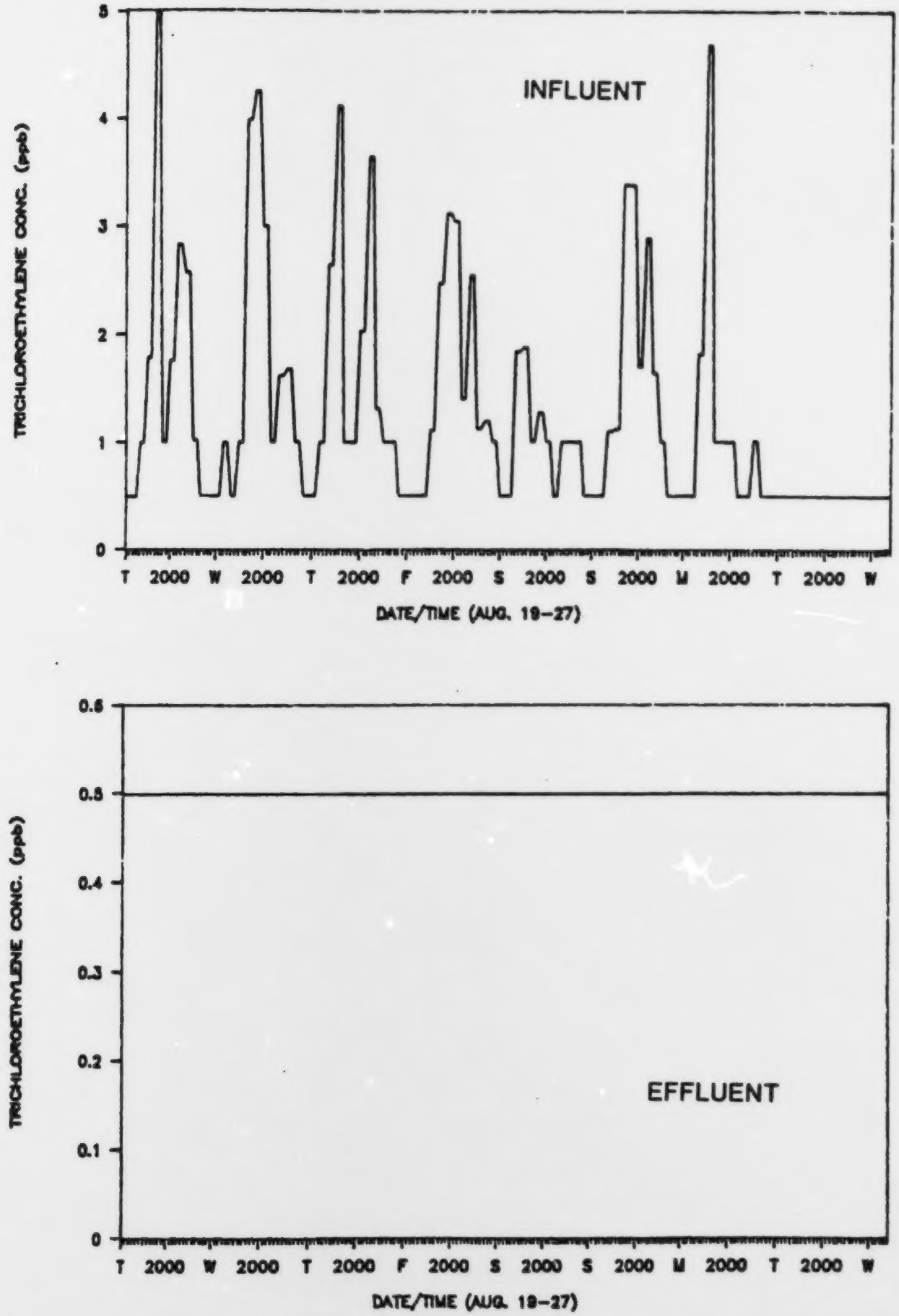


FIGURE 75: CHRONOLOGY OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE AT WELLAND WPCP

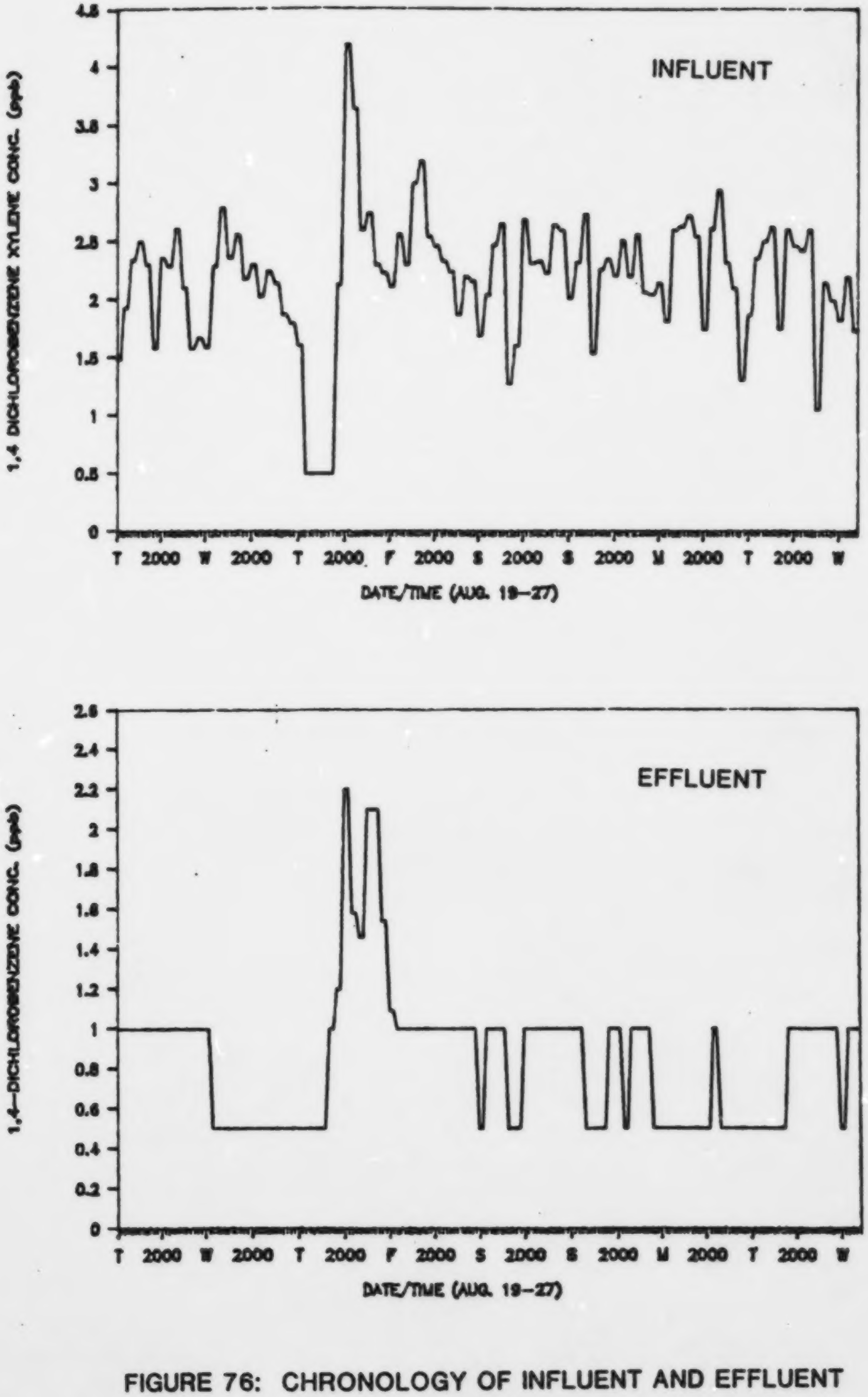


FIGURE 76: CHRONOLOGY OF INFLUENT AND EFFLUENT 1,4 DICHLOROBENZENE AT WELLAND WPCP

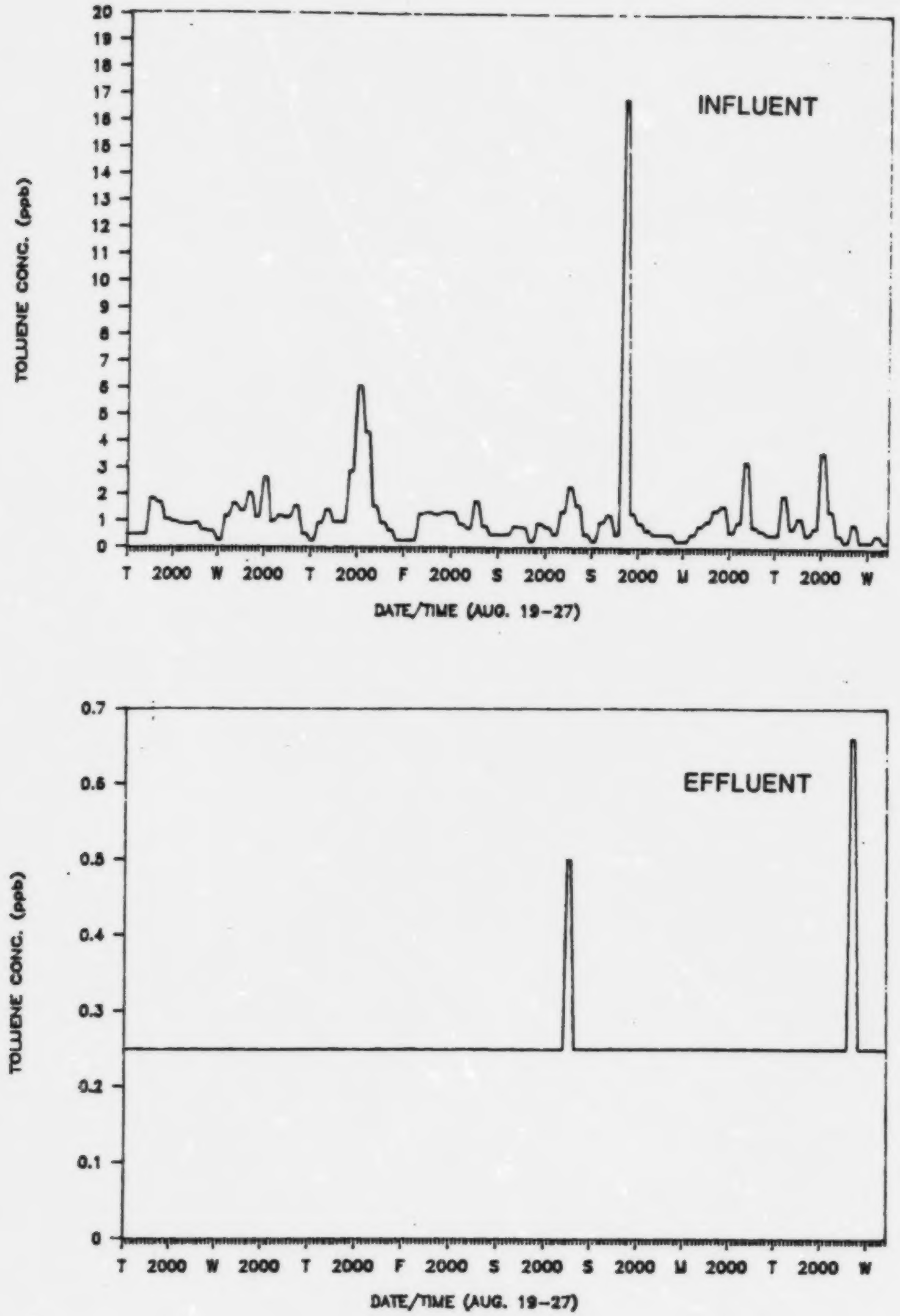
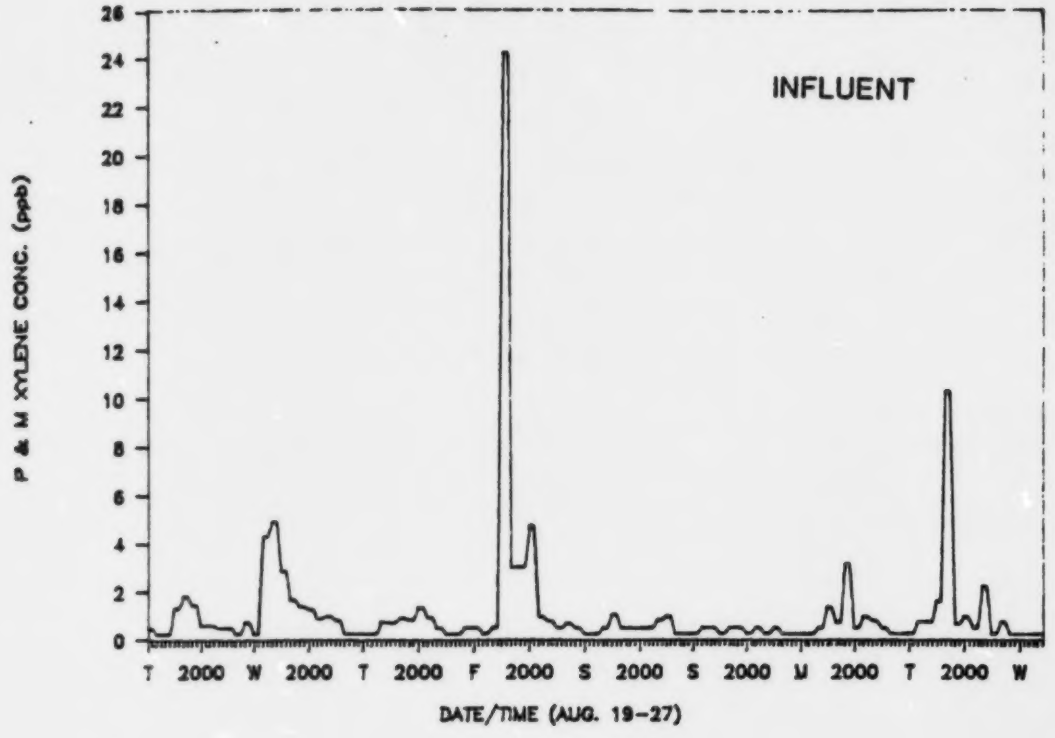


FIGURE 77: CHRONOLOGY OF INFLUENT AND EFFLUENT TOLUENE AT WELLAND WPCP



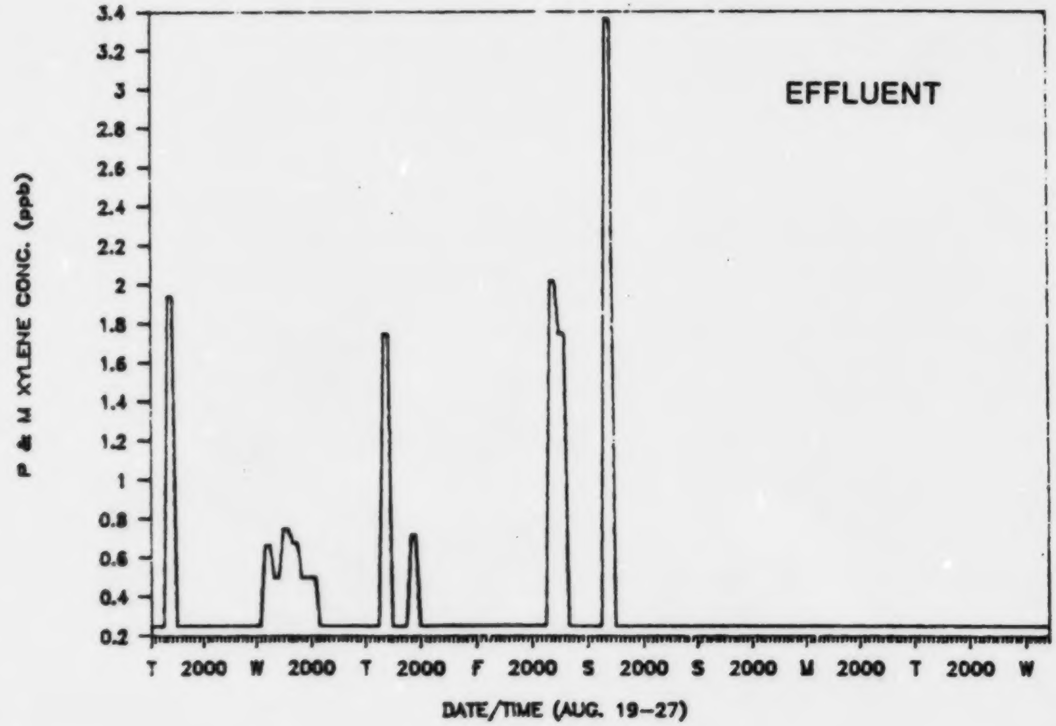


FIGURE 78: CHRONOLOGY OF INFLUENT AND EFFLUENT P&M XYLENE AT WELLAND WPCP

Table 40
FREQUENCY OF DETECTION OF PAHs AT WELLAND STP

	Frequency of Detection (%)					
	Influent			Effluent		
Compound	> MDL*	> Trace	Range (µg/L)	> MDL*	> Trace	Range (µg/L)
Acenaphthene	0	0	ND	0	0	ND
Acenaphthylene	0	0	ND	10	10	ND-1.8
Anthracene	0	0	ND	0	0	ND
Phenanthrene	30	90	ND-1.1	50	90	ND-0.06
Benzo(a)anthracene	0	30	ND-Trace	0	0	ND
Chrysene	0	0	ND	0	0	ND
Benzo(b)fluoranthene	30	60	ND-0.35	0	70	ND-Trace
Benzo(k)fluoranthene	0	60	ND-Trace	0	70	ND-Trace
Benzo(ghi)perylene	0	0	ND	0	0	ND
Dibenzo(ah)anthracene	0	0	ND	0	0	ND
Fluoranthene	70	90	ND-1.2	30	80	ND-0.03
Fluorene	50	80	ND-2.2	0	0	ND
Indeno(1,2,3-cd)pyrene	0	0	ND	0	0	ND
Naphthalene	0	0	ND	0	0	ND
Pyrene	40	70	ND-1.9	60	100	Trace-0.28
Benzo(a)pyrene	30	70	ND-0.37	0	80	ND-Trace

* MDL varied from sample to sample depending on extraction volume and sample type but generally was in the range 0.05 µg/L to 0.5 µg/L.

Recovery of the internal surrogate, terphenyl, in Welland samples was low, but consistent with that observed at Waterloo. Average recovery in raw sewage samples was 27.3 percent (±9.8%) and in secondary effluents was 26.0 percent (±7.0%). The reported concentrations are not corrected for analytical recovery.

4.3 Variability of Trace Contaminant Concentrations

The relative variability of influent and effluent concentrations of selected conventional contaminants, metals and trace organics is summarized in Table 41, where variability

Table 41
VARIABILITY OF INFLUENT AND EFFLUENT AT WELLAND STP

Contaminant	Influent RSD (%)	Influent 95th %ile / Geo. Mean	Effluent RSD (%)	Effluent 95th %ile / Geo. Mean	Influent:Effluent Ratio RSD	Influent:Effluent Ratio 95th %ile / Geo. Mean
FOC	74.6	3.29	11.0	1.17	6.78	2.81
TSS	88.0	4.26	47.4	1.77	1.86	2.41
Total P	39.6	1.81	22.6	1.42	1.75	1.27
Filt. P	43.9	1.89	22.0	1.33	2.00	1.42
Cadmium	41.4	2.00	34.6	1.79	1.20	1.12
Chromium	55.8	2.62	18.3	1.36	3.05	1.93
Copper	45.5	1.85	41.3	2.07	1.10	0.89
Nickel	36.4	1.74	18.8	1.38	1.94	1.26
Lead	133.	5.38	60.7	1.66	2.19	3.24
Zinc	66.4	2.79	33.2	1.74	2.00	1.60
Total Phenols	66.9	2.59	80.8	3.40	0.82	0.76
Chloroform	72.5	3.87	33.3	1.38	2.17	2.80
Trichloroethylene	84.6	4.00	-	-	-	-
1,4-dichlorobenzene	27.3	1.33	44.4	1.88	0.61	0.71
Toluene	150.	4.00	-	-	-	-
p, m-xylene	225.	5.50	125.0	1.33	1.80	4.13

(KIR21/272W)

is reported both as relative standard deviation (RSD, percent) and as the ratio of the 95th percentile concentration to the geometric mean.

All conventional contaminants showed considerably less variability in the effluent than in the influent, confirming the attenuation exhibited at the Waterloo STP in terms of conventionals. At Welland, phosphorus (total and filtered) which was controlled throughout the monitoring period by effective chemical addition, showed an effluent variability more consistent with the other conventional contaminants than was evident at the Waterloo STP. All of the metal species, with the exception of copper, exhibited less variability in the effluent than in the influent. Since effluent concentrations of several metals, including copper, were at near detection levels, the lack of analytical resolution may have affected the apparent effluent variability. In general, the influent-to-effluent variability ratios of the metals appeared to be lower than comparative data for conventional contaminants.

For trace organics identified frequently in influents and effluents, the variability data suggest that some compounds (phenols and 1,4-dichlorobenzene) are more variable in effluents than in influents whereas for others (chloroform and p&m-xylene), the opposite is the case. At Welland, more so than at Waterloo, the low frequency of detection and near detection limit concentrations affects the results of the data analyses.

Normalized variances for selected compounds in each major category (conventionals, metals, organics) are compared in Table 42. Based on an F-test of these data, all classes of contaminants showed a lesser degree of variability in effluents than in influents at Welland. In the influent samples, conventional contaminants were marginally but significantly less variable than metals which were considerably less variable than trace organics. The same order of variability was apparent in the effluent sample, although the difference between conventionals and metals, in terms of the degree of variability, was greater. The same order was apparent in effluent samples at the Waterloo STP.

Table 42
COMPARISON OF INFLUENT AND EFFLUENT VARIABILITY
AT WELLAND STP

Contaminant Group	Normalized Variance	
	Influent	Effluent
Conventionals*	0.415	0.082
Metals**	0.504	0.140
Organics***	1.533	0.395

---

* Conventionals includes FOC, TSS, TP, Filt. P

** Metals includes Cd, Cr, Cu, Ni, Pb, Zn

*** Organics includes total phenols, chloroform, trichloroethylene, 1,4-dichlorobenzene, toluene and p&m-xylene

Based on the variability criterion of the 95th percentile value exceeding the geometric mean by a factor of 2.0, none of the conventional contaminants and only copper of the metal species showed significant effluent variability although FOC, TSS, cadmium, chromium, lead and zinc exceeded the variability criteria in influent samples. Of the organics frequently detected in influents, total phenols, chloroform, trichloroethylene, 1,4-dichlorobenzene, toluene and p&m-xylene exceeded the criterion in influent samples but only phenol exhibited significant variability in the Welland STP effluent.

4.4 Toxicity of Influents and Effluents

The results of the 48-hour Daphnia and 96-hour rainbow trout static acute toxicity bioassays performed on the Welland STP raw influent, unchlorinated secondary and final chlorinated effluents are shown in Table 43. Mortality generally occurred within the first 24-hours of the testing period.

In all samples, temperature and dissolved oxygen levels remained stable throughout the exposure time at 15±1°C and above 8 mg/L respectively, while the pH values increased slightly in all samples (Table 44).

Table 43

RESULTS OF ACUTE LETHALITY TESTING PERFORMED ON THE WELLAND SEWAGE TREATMENT PLANTS EFFLUENT SAMPLES

Date/Time	Undiluted Plant Influent			Undiluted Treated/Chlorinated			LC50 (% v/v . 95% Confidence Limits)					
							Plant Influent		Secondary/ Non-chlorinated		Secondary/Chlorinated	
	Total NH_3-N (mg/L)	Un-ionized NH_3 (mg/L)	TRC (mg/L)	Total NH_3-N (mg/L)	Un-ionized NH_3 (mg/L)	TRC (mg/L)	Daphnia (% v/v)	Trout (% v/v)	Daphnia (% v/v)	Trout (% v/v)	Daphnia (% v/v)	Trout (% v/v)
High Waste Load Condition												
19 Aug 86/10:00	19.5	0.07	L 0.05	7.2	0.05	0.11	N.L. (10)*	-	N.L.	-	N.L.	-
20 Aug 86/10:00	25.0	0.14	L 0.05	3.5	0.01	0.68	N.L.	95 (75-100)	N.L.	N.L. (10)*	N.L.	N.L
22 Aug 86/10.00	19.5	0.15	L 0.05	7.0	0.03	1.10	N.L.	-	N.L.	-	17 (13-22) N.L. (Dcl)	-
23 Aug 86/10:00	25.0	0.12	L 0.05	11.3	0.05	0.72	-	-	-	-	8 (6-10) 25 (Dcl) (20-30) 71 (NH_3 out) (50-100)	-
24 Aug 86/10:00	30.0	0.13	L 0.05	5.5	0.02	L 0.05	71 (50-100)	78 (61-99)	N.L.	N.L.	N.L.	N.L.
27 Aug 86/10:00	24.0	0.12	L 0.05	1.6	0.02	0.70	N.L.	-	N.L.	-	12 (10-16) N.L. (Dcl)	-
Low Waste Load Condition												
20 Aug 86/04.00	20.0	0.10	L 0.05	9.15	0.06	0.5	N.L.	71 (50-100)	N.L.	N.L.	N.L.	N.L. (10)*
21 Aug 86/04:00	22.0	0.07	L 0.05	10.5	0.06	0.45	N.L.	-	N.L.	-	N.L. (20)	-
22 Aug 86/04:00	19.5	0.12	L 0.05	9.5	0.04	0.65	N.L. (10)*	-	N.L.	-	N.L.	-
24 Aug 86/04:00	25.0	0.07	L 0.05	6.0	0.01	L 0.05	N.L.	71 (50-100)	N.L.	N.L.	21[1] (17-27) N.L. (Dcl)	N.L.
27 Aug 86/04:00	10.5	0.06	L 0.05	7.0	0.05	0.35	N.L.	-	N.L.	-	N.L.	-

Total NH_3-N = Total ammonia nitrogen measured by Nesslerization method.

NH_3 = Un-ionized ammonia; calculated according to Emmerson et al. (1975).

NH_3 Out = Ammonia removed by clinoptilolite.

LC50 = Median lethal concentration.

TRC = Total residual chlorine measured by DPD method.

Dcl = Dechlorinated.

N.L. = Non-lethal.

* = Some mortality observed. Brackets indicate % mortality observed in undiluted sample only.

1 = Sample was aerated to increase D.O. prior to introducing trout (2 hrs) and Daphnia (5 min); greater Daphnia toxicity likely due to higher TRC at beginning of test.

( ) = 95% confidence interval about the LC50.

Table 44
INITIAL PHYSICAL AND CHEMICAL PARAMETERS OF THE UNDILUTED EFFLUENT SAMPLES FROM THE WELLAND SEWAGE TREATMENT PLANT

Sample	Date/Time Sample Collected	Oxygen (mg/L)	pH	Conductivity (umhos/cm)	Temperature (°C)	Total Chlorine (mg/L)	Total Ammonia (mg/L)
Plant Influent	19.08.86/10:00	1.2	6.86	560	21	L 0.05	19.5
	20.08.86/04:00	0.25	6.98	620	21	L 0.05	20.0
	20.08.86/10:00	0.35	7.08	750	21	L 0.05	22.0
	21.08.86/04:00	0.8	6.85	600	21	L 0.05	25.0
	22.08.86/04:00	0.6	7.1	600	21	L 0.05	9.5
	22.08.86/10:00	0.4	7.2	600	21	L 0.05	19.5
	24.08.86/04:00	0.15	6.77	640	21	L 0.01	25.0
	24.08.86/10:00	0.2	6.93	700	21	L 0.01	30.0
	27.08.86/04:00	0.7	6.9	425	21	L 0.05	10.5
	27.08.86/10:00	0.6	7.0	620	21	L 0.05	24.0
Secondary Effluent	19.08.86/10:00	3.4	6.81	560	21		
	20.08.86/04:00	2.6	7.04	600	21		
	20.08.86/10:00	2.8	6.89	550	21		
	21.08.86/04:00	5.2	7.11	600	21		
	22.08.86/04:00	2.2	6.85	480	21		
	22.08.86/10:00	3.8	7.1	490	21		
	24.08.86/04:00	4.8	6.63	440	21		
	24.08.86/10:00	3.9	6.83	460	21		
	27.08.86/04:00	2.8	7.0	400	21		
	27.08.86/10:00	5.1	7.05	405	21		
Treated/Chlorinated Effluent	19.08.86/10:00	5.8	7.12	600	21	0.11	7.2
	20.08.86/04:00	4.1	7.17	600	21	0.5	9.15
	20.08.86/10:00	3.7	6.88	590	21	0.68	3.5
	21.08.86/04:00	5.6	7.1	650	21	0.45	10.5
	22.08.86/04:00	5.4	6.9	475	21	0.65	9.5
	22.08.86/10:00	5.6	7.0	480	21	1.10	7.0
	23.08.86/10:00	3.6	7.0	600	21	0.72	11.3
	24.08.86/04:00	4.8	6.65	440	21	0.01	6.0
	24.08.86/10:00	3.2	6.93	700	21	0.01	5.5
	27.08.86/04:00	6.1	7.15	400	21	0.35	7.0
	27.08.86/10:00	6.4	7.3	405	21	0.70	1.6

4.4.1 Species Sensitivity

Review of Table 43 indicates that sensitivity varied between trout and *Daphnia*. Three of the four influent samples were toxic to trout but non-lethal to *Daphnia*, while the fourth sample was equally toxic to both organisms (24 August, high load). Only one of the secondary non-chlorinated samples out of the four tested with both species produced low level lethality (10 percent in undiluted sample) to trout. The rest were non-lethal.

One out of the four secondary chlorinated samples tested with both organisms was lethal to *Daphnia* (LC50 = 21 percent), but was non-lethal to trout (24 August, low load). Addition of sodium sulphite to remove chlorine rendered the sample non-lethal to *Daphnia*. This particular sample arrived in the laboratory with a very low dissolved oxygen concentration which required aeration prior to testing. The trout sample was aerated for about two hours and the *Daphnia* sample for only several minutes. It is possible that lethal levels of chlorine were stripped from the trout sample, but were present in the *Daphnia* sample to produce lethality in the latter case only. Two of the remaining samples were non-lethal to both trout and Daphnia, but the 20 August 'low load' sample was slightly toxic to trout (10 percent mortality in undiluted sample) and non-lethal to *Daphnia*. These test comparisons between species demonstrated that effluents toxic to one organism were not consistently toxic to the other. In one case, this can be accounted for by procedural differences.

4.4.2 Waste Loading and Treatment

Three influent samples were lethal during 'high waste load' conditions as compared to two during 'low loading'. The frequency of acute lethality in the secondary chlorinated effluent also appeared to be lower during "low waste load" conditions (1/5 samples lethal) compared to "high waste load" periods (3/5 samples lethal). At least some of the chlorinated effluent toxicity was related to chlorine residual and, in three of the four effluents, lethality was eliminated in *Daphnia* tests after residual chlorine was removed.

In most cases, the secondary treated effluents were non-lethal to *Daphnia* and trout. Only slight toxicity to trout was observed in one sample (20 August, high load) when 10 percent mortality occurred in undiluted sample. Chlorination of the secondary effluent produced lethality in *Daphnia* in four out of the ten samples tested. Three of these lethal bioassay samples were rendered non-lethal when chlorine residues were eliminated by sodium sulphide treatment. One final effluent sample (23 August, high flow) was still toxic after dechlorination and ammonia removal. The *Daphnia* LC50 changed from 8 percent v/v (original) to 25% v/v (after chlorine removal) to 71 percent v/v (after ammonia removal), indicating that residual toxicants remained.

4.4.3 Chlorine

Chlorine is the most obvious potential toxicant in chlorinated effluent samples. Studies of chlorine toxicity(15,16,31) indicated that residual chlorine toxicity is species- and time-dependent. Arthur *et al*(15) clearly identified the greater sensitivity of fish (brook trout, coho salmon, fathead, sucker, walleye) to chlorinated sewage effluent than invertebrates (gammarus, stonefly, caddisfly, crayfish, snails). The seven-day LC50 values for fish ranged from 0.08 to 0.26 mg TRC/L, and for invertebrates from 0.2 to greater than 0.8 mg TRC/L. Larson *et al*(16) identified that trout (coho salmon, brook trout, cutthroat trout) may live indefinitely at TRC concentrations near 0.05 mg/L. While some of the TRC values reported in this study exceeded these levels, no relationship exists between the concentrations measured and observed lethality. It is well recognized that sample aeration during tests causes chlorine concentrations to decline exponentially. In addition, the DPD method of TRC analysis does not provide accurate TRC measurements under approximately 0.05 mg/L. Therefore, the above discrepancies between chlorine toxicity and organism sensitivity may be accounted for by dynamic changes in TRC concentrations in the test vessel and poor detection limits for the DPD analytical method. No conclusions can be drawn concerning the importance of TRC from this study. Future tests employing continuous-flow techniques to ensure consistent TRC levels and more sensitive analytical measurement would clarify this issue.

4.4.4 Ammonia and Other Contaminants

Ammonia concentrations were presented in Table 43 as total ammonia nitrogen and the more toxic, un-ionized form. Un-ionized ammonia values were derived from the total ammonia concentrations using the pH and temperature of the bioassay sample(32). Rainbow trout 96-hour LC50's have been reported in the literature to range from 0.1 to 0.8 mg un-ionized ammonia/L(14). Daphnia magna are much more tolerant of un-ionized ammonia than fish, with 48-hour LC50's reported between 2 to 3 mg/L(14).

Rainbow trout lethality was observed in all four influent samples tested. Since the influent was not chlorinated, ammonia was one alternative measured toxicant. The samples contained un-ionized ammonia concentrations near or exceeding acutely lethal levels. Daphnia are less sensitive to ammonia, and the influent sample which was lethal to Daphnia contained un-ionized ammonia of only 0.13 mg NH_3/L. In addition, some non-lethal samples contained equal or greater ammonia levels, indicating that the samples lethal to Daphnia must have contained other contaminants. Inorganics (Table 45) and organics (Table 46) had been measured in subsamples of those tested for toxicity since they were collected at the same time as those collected for chemical characterization. Comparison with documented toxic ranges of those toxicants in Table 28 indicates that only copper was present in sufficient quantity to contribute to Daphnia toxicity (44 percent of LC50), while the influent samples lethal to trout all contained copper levels exceeding their reported LC50 of 20 µg/L. One of the those influent samples lethal only to trout also contained levels of zinc which were greater than reported LC50 values for both trout and Daphnia. Thus, the role of metals in influent toxicity is uncertain.

Review of the estimated un-ionized ammonia level in the 23 August (high load) chlorinated effluent sample (0.05 mg NH_3/L) is about 40-fold less than the documented Daphnia value (2 mg/L). The results of this single test suggest that one or more other toxicants were present. The sample was treated with clinoptilolite to remove NH_3, and reduced toxicity was observed. Clinoptilolite has been reported to remove other cations, however, such as Cu^{++} and Zn^{++} in addition to NH_4^+(33). Most metal concentrations in the

Table 45

CONCENTRATIONS OF INORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENTS

Sample Date	P (mg/L)		P (filt.) (mg/L)		Cd (ug/L)		Cr (ug/L)		Cu (ug/L)		Ni (ug/L)		Pb (ug/L)		Zn (ug/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Load																
19.08.86	2.49	0.92	1.33	0.47	3	3	11	10	19	5	14	17	5	5	37	25
20.08.86[c]	3.66	0.94	2.00	0.53	1	1	9	8	22	7	7	11	5	5	66	28
22.08.86[b]	2.09	0.80	1.20	0.40	5	4	20	17	17	11	16	18	5	5	42	20
23.08.86[b]	2.85	0.91	2.13	0.57	4	3	13	10	19	4	14	16	5	5	43	20
24.08.86[c,d]	3.51	0.85	2.00	0.55	3	2	14	8	35	4	15	12	5	5	52	17
27.08.86[b]	2.65	0.56	1.47	0.33	2	3	12	8	26	4	14	15	5	5	58	14
Low Load																
20.08.86[c]	3.44	0.87	2.13	0.53	3	2	13	6	22	3	12	12	5	5	29	36
21.08.86	3.45	0.92	1.87	0.67	3	1	13	8	17	7	14	9	5	5	39	23
22.08.86	2.92	0.86	1.73	0.53	3	3	23	9	19	6	20	13	5	5	36	25
24.08.86[b,c]	5.74	0.81	2.27	0.53	3	2	21	8	93	6	23	11	5	5	185	22
27.08.86	1.74	0.69	0.93	0.37	2	2	12	6	18	4	12	11	10	5	65	14

[a] Non-chlorinated and [b] chlorinated sample toxic to *Daphnia magna*.

[c] Influent sample toxic to *Salmo gairdneri*.

[d] Influent sample toxic to *Daphnia magna*.

Table 46
CONCENTRATIONS OF ORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENT (µg/L)

Sample Date	Phenolics	Chloroform		1,4-Dichlorobenzene		Trichloroethylene		Toluene		P&M-Xylene	
		In	Out	In	Out	In	Out	In	Out	In	Out
High Load											
19.08.86	3.4	6.67	1.00	1.93	1.00	1.00	0.50	0.50	0.25	0.25	0.25
20.08.86[c]	5.0	4.19	1.00	2.29	0.50	1.00	0.50	1.17	0.25	4.32	0.67
22.08.86[b]	3.4	3.33	1.00	2.56	1.00	0.50	0.50	0.25	0.25	0.25	0.25
23.08.86[b]	1.0	3.73	1.01	2.04	1.00	0.50	0.50	0.50	0.25	0.25	0.25
24.08.86[c,d]	2.4	5.73	1.14	2.32	1.00	0.50	0.50	0.95	0.25	0.50	0.25
27.08.86[b]	1.0	0.50	2.19	2.19	1.00	0.50	0.50	0.50	0.25	0.25	0.25
Low Load											
20.08.86[c]	5.0	2.75	1.00	1.58	1.00	0.50	0.50	0.63	0.25	0.25	0.25
21.08.86	2.4	4.71	1.00	1.87	0.50	1.00	0.50	1.54	0.25	0.25	0.25
22.08.86	8.8	3.40	1.00	2.30	2.10	1.00	0.50	0.63	0.25	0.25	0.25
24.08.86[b,c]	1.6	3.56	1.00	2.64	1.00	1.00	0.50	1.58	0.25	0.25	0.25
27.08.86	2.4	3.10	0.50	2.14	1.00	0.50	0.50	0.91	0.66	0.76	0.25

[a] Non-chlorinated and [b] chlorinated sample toxic to *Daphnia magna*.

[c] Influent sample toxic to *Salmo gairdneri*.

[d] Influent sample toxic to *Daphnia magna*.

chlorinated effluent were as much as two orders of magnitude below LC50 values, except for zinc which was present at 20 to 36 percent of the lowest documented LC50 for Daphnia (100 µg/L).

The above information indicates that analytical measurement of contaminants provides a poor estimate of effluent toxicity. The changing composition of sewage effluent and the different sensitivity of trout and Daphnia to those toxicants results in one organism being a poor surrogate for the other in toxicity evaluations.

4.5 Prediction of Welland STP Influent Quality

The dry weather flow component of HAZPRED was used to predict concentrations of selected trace contaminants in the influent to the Welland STP. The industrial contributions to the facility were based on data provided by the Regional Municipality of Niagara and summarized in Table 9. Commercial and residential water consumption records from the local utility were used to define these components of the STP influent. From the flow, industrial SIC and the industrial/commercial/residential wastewater characterization data contained in HAZPRED, concentrations of heavy metals including cadmium, chromium, copper, lead, nickel and zinc were predicted. For organics, only the concentrations of compounds found at a high frequency in the raw wastewater were predicted. This list was limited to chloroform, toluene, and trichloroethylene since p&m-xylene and 1,4-dichlorobenzene were not contained in the HAZPRED data base. Benzene was also included in the prediction although not detected at a high frequency during the monitoring period.

Table 47 presents the predicted and observed geometric mean concentrations for the selected compounds, along with the logarithmic ratio of these values. As was the case for the HAZPRED predictions of raw wastewater quality at the Waterloo STP, the predicted values are generally within an order-of-magnitude of the actual values. However, the observed values were consistently low compared to the predicted values and the deviation was generally greatest for the organic contaminants. For example, benzene was predicted to be present at concentrations exceeding 2.5 mg/L but was not detected during the monitoring program in more than 20 percent of the samples. Similarly, toluene was predicted to be present at concentrations exceeding 0.5 mg/L but was measured at an average concentration of less than 1 µg/L. There was generally better agreement between the predicted and observed metal concentrations than between the predicted and observed organic concentrations.

Table 47

COMPARISON OF PREDICTED AND OBSERVED INFLUENT

CONCENTRATIONS AT WELLAND STP

	Concentration (µg/L)		
Contaminant	Observed	Predicted	Log Ratio
Chloroform	3.90	14 .20	-0.56
Toluene	0.80	536.09	-2.83
Benzene	ND	2529.99	-
Trichloroethylene	1.00	2.55	-0.41
Cadmium	2.70	5.89	-0.34
Chromium	14.90	55.04	-0.57
Copper	30.90	37.41	-0.08
Lead	8.30	62.32	-0.88
Nickel	14.40	15.59	-0.03
Zinc	64.90	253.05	-0.59

The relatively high concentrations of organic compounds predicted in the Welland STP influent by HAZPRED are consistent with the heavy industrial profile tributary to the plant. However, the collection system serving the City of Welland contained a relatively high proportion of combined sewers and the plant is subjected to considerable extraneous flow during wet weather periods as indicated by the low strength wastewater historically reported (Table 7) in terms of BOD_5, TSS and TP. This is a major factor in reducing the influent concentrations of trace contaminants compared to those which are predicted based on the industrial profile. Predicted flows from the HAZPRED model for the Welland STP (32,860 m^3/d) agreed well with the flows observed during the sampling period (30,570 m^3/d).

5.0 GALT STP RESULTS

5.1 Plant Operation and Performance

The intensive sampling program at the Galt STP (September 30 to October 8, 1986) occurred during a period of high precipitation, resulting in abnormally high flows at the facility. Average flow for the monitoring period was 36,800 m^3/d compared to a two year average (September 1984 to September 1986) flow of 30,910 m^3/d. Peak flows on September 29, September 30 and October 1, the periods of highest precipitation, were 93,200 m^3/d, 68,200 m^3/d and 72,000 m^3/d respectively. As a result of these high flows, effluent quality was significantly poorer in terms of effluent suspended solids than typically achieved by the Galt STP. The effect of high hydraulic loading on the plant was exacerbated by experimentation with ferrous chloride for phosphorus removal. The plant staff were in the process of optimizing dosage and addition point after switching to ferrous chloride on September 11. The sampling program was also affected by the inadvertent discharge of digester supernatant to the plant headworks on October 7 as noted in Section 2.2.3 of the report. This supernatant discharge impacted on raw sewage quality on the final day of the intensive sampling program.

Flow data and influent and effluent quality data for the period September 20 to October 8 encompassing the intensive sampling period (and the period when ferrous chloride was used for phosphorus removal) are presented in Table 48. Flows for this three week period were approximately 10 percent higher than the long-term average and near 90 percent of the plant design flow. Raw sewage quality was comparable, in terms of BOD_5, TSS and TP concentrations, to the long-term average (Table 11). However, the final effluent quality for this period was significantly poorer than typical of the Galt STP as a result of high flows and the experimentation with ferrous chloride for phosphorus removal. During this period, the plant did not meet its effluent objectives of 25 mg/L BOD, 25 mg/L TSS and 1.0 mg/L TP.

Table 48
GALT STP PERFORMANCE
(September 20 to October 8)

Average Daily Flow	33,660 m^3/d
Influent Quality	
BOD_5 (mg/L)	168
TSS (mg/L)	196
TP (mg/L)	5.7
Effluent Quality	
BOD_5 (mg/L)	29
TSS (mg/L)	39
TP (mg/L)	1.11

Average operating conditions during the period of September 30 to October 8 are summarized in Table 49. In general, operating conditions were typical with the exception of the high flow at the plant. The system SRT during this period, at approximately 2.1 days, was lower than normal due to the loss of suspended solids to the plant effluent during the intensive monitoring period.

Table 49
AVERAGE OPERATING CONDITIONS AT WELLAND STP
(September 30 to October 8)

MLSS (mg/L)	1230
MLVSS (mg/L)	900
F/M (kg/kg.d)	0.88
SVI	56
DO Range (mg/L)	1.8 - 3.0
SRT (days)	2.1

5.2 Intensive Sampling Program Results

5.2.1 Conventional Contaminants

A probability distribution of Galt STP raw sewage flow during the intensive sampling period is presented in Figure 79. Geometric mean flow during this period was 35,400 m^3/d and the distribution followed a log-normal pattern. A strong diurnal trend in the flow data is apparent in Figure 80, with the highest flows occurring early in the sampling program (September 30 and October 1) coincidental with the rainfall during this period.

Probability distributions for influent and effluent FOC, influent TKN and effluent NH_3-N, influent and effluent TSS and influent and effluent total and filtered phosphorus are presented in Figures 81 to 85, respectively. Key statistical data for these conventional contaminants are summarized in Table 50. The intensive sampling data confirm the plant data which indicated poorer than normal effluent quality due to suspended solids carryover. The intensive data also suggest a weaker raw sewage than typical of the Galt STP, which is probably reflective of the rainfall which occurred during this sampling period. These data also suggest that some degree of nitrification was occuring in the plant based on removal of influent TKN concentrations of 20.9 mg/L to average NH_3-N levels in the effluent of 11.4 mg/L; however, as nitrate was not monitored in the plant effluent, the occurrence of nitrification could not be verified.

A chronological plot of influent FOC concentrations (Figure 86) shows a significant diurnal trend which is reproduced to a much lesser extent in the effluent. Any diurnal trend in the TSS data (Figure 87) appears to be masked by the rainfall early in the sample program and the inadvertent supernatant recycle on October 7. Although there is no significant diurnal cycle in the 8 day data sequence, there does appear to be a diurnal trend during the middle three to five days of the program. A significant diurnal trend is evident in the effluent TSS data. Total and filtered phosphorus show strong diurnal trends in both influents and effluents in Figures 88 and 89. The effect of supernatant return on the influent TP concentration was apparent in Figure 88. The

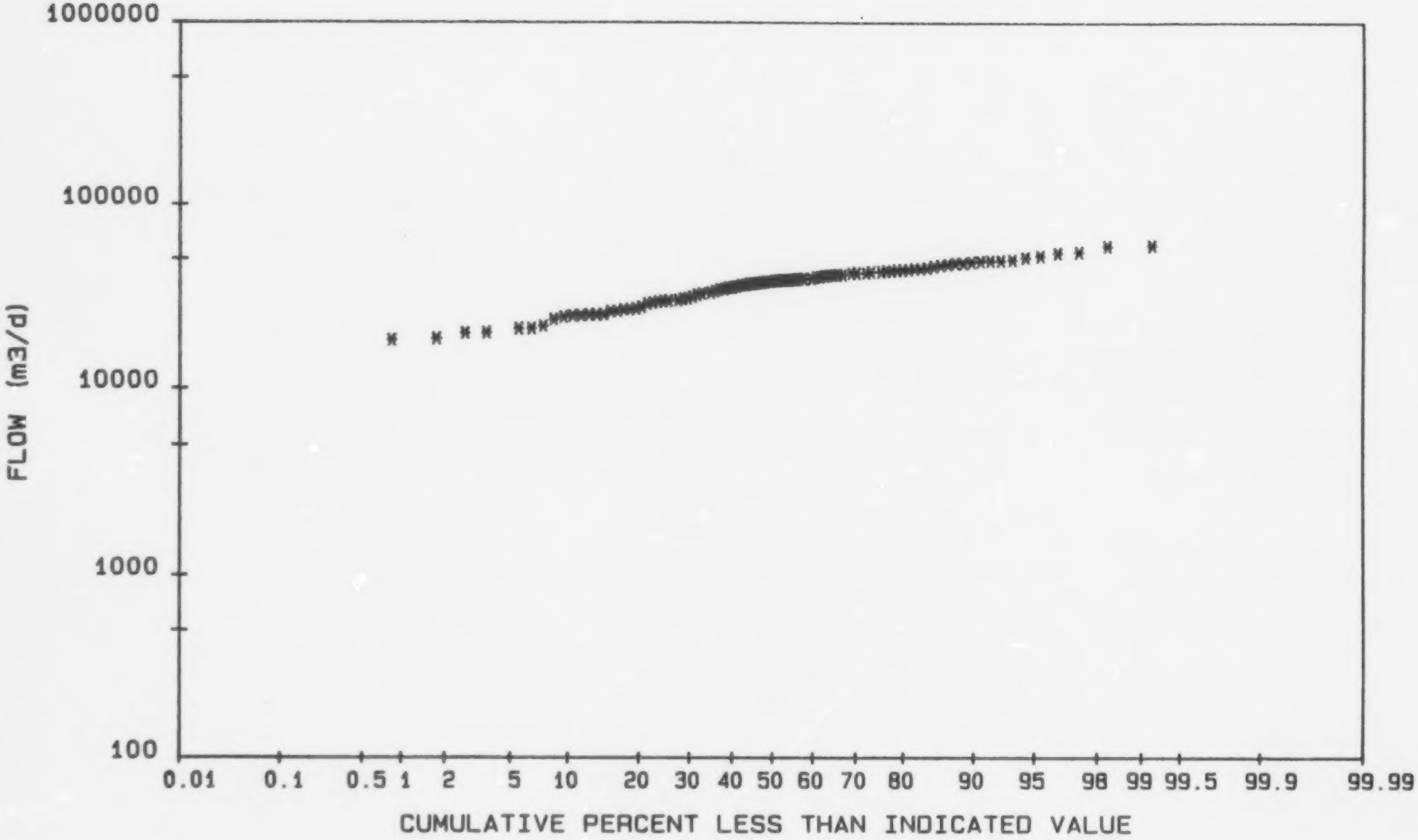


FIGURE 79 PROBABILITY DISTRIBUTION OF FLOW DATA AT GALT STP

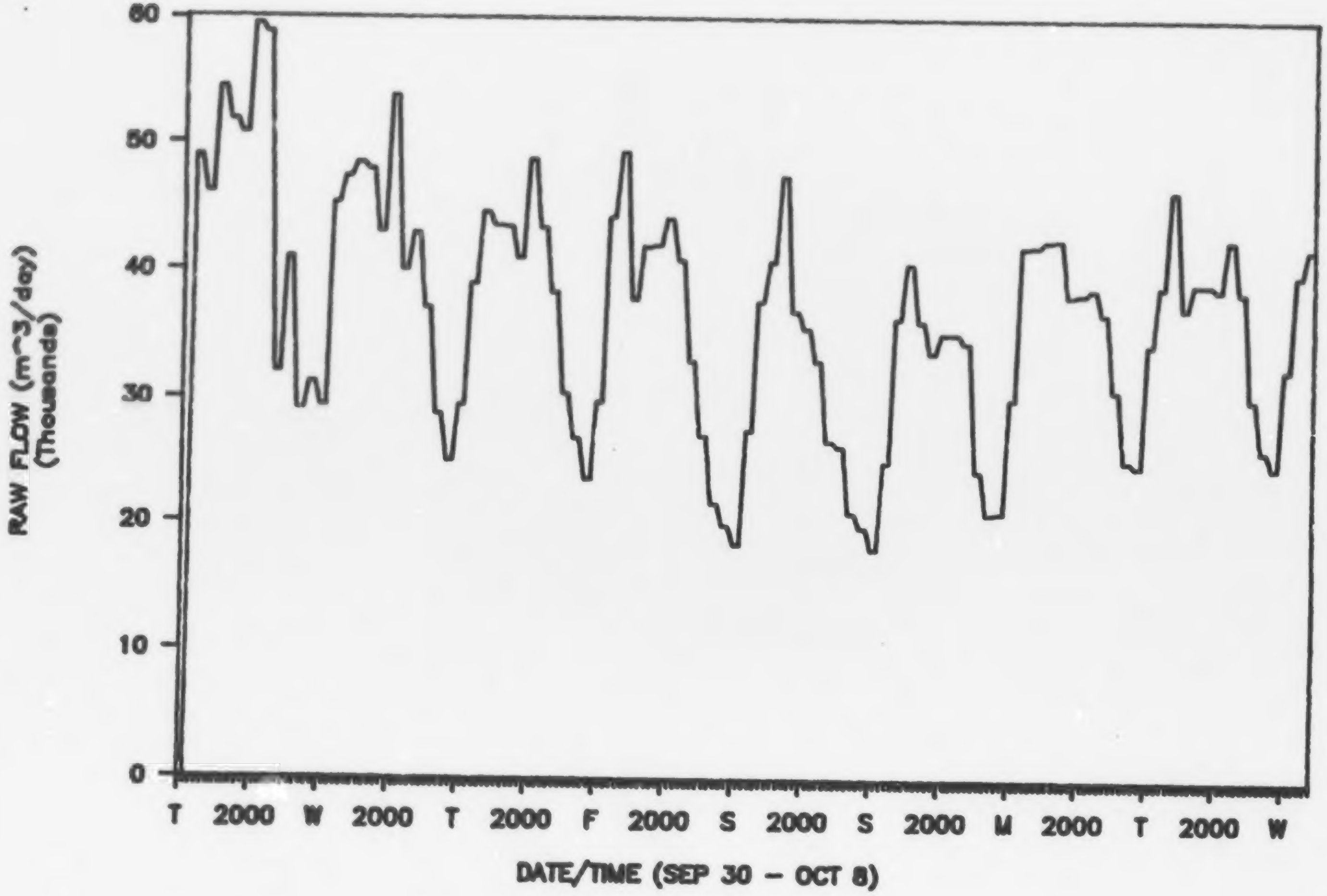


FIGURE 80: CHRONOLOGICAL FLOW PATTERN AT GALT WPCP

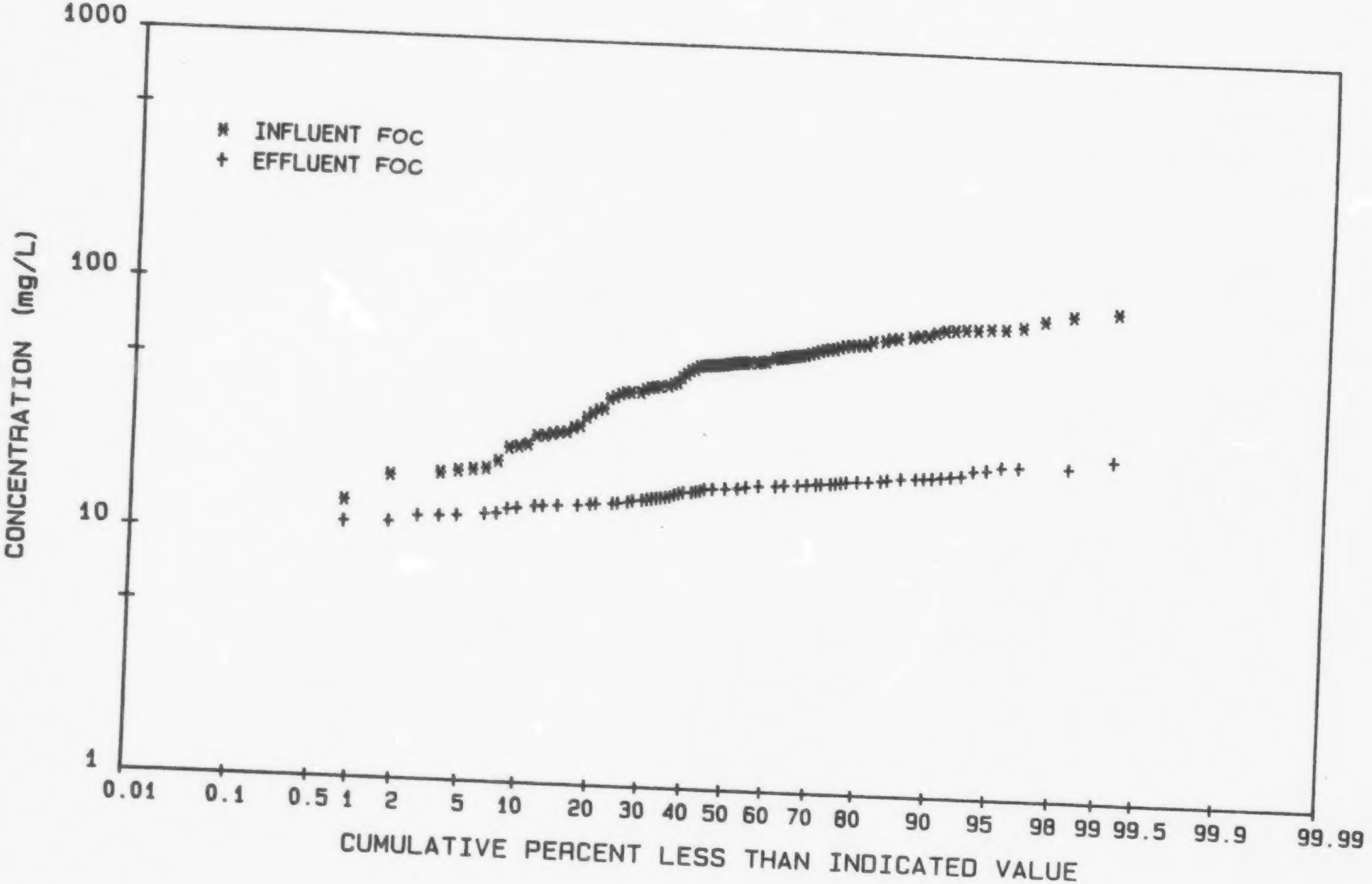


FIGURE 81 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FOC CONCENTRATION AT GALT STP

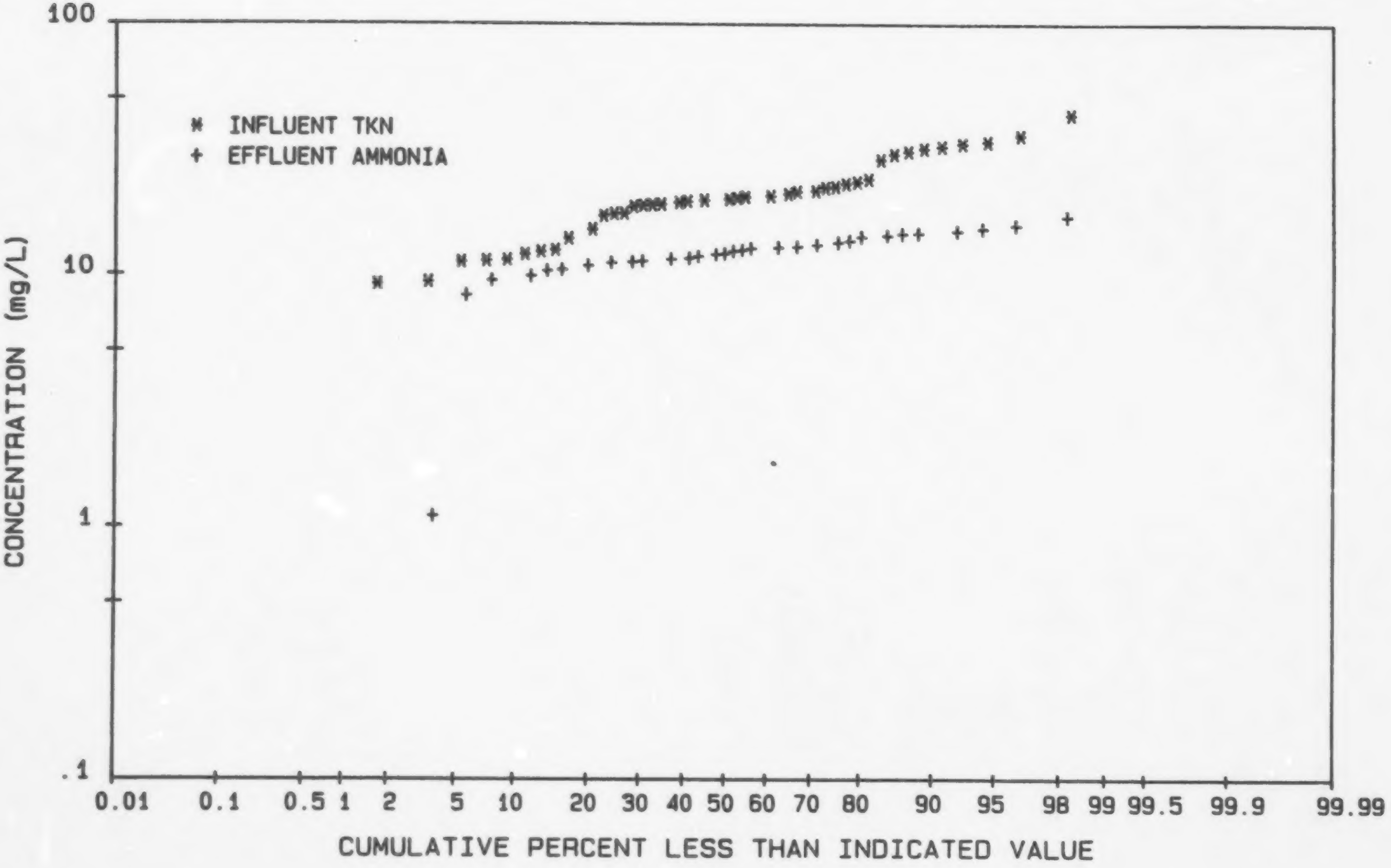


FIGURE 82 PROBABILITY DISTRIBUTION OF INFLUENT TKN AND EFFLUENT AMMONIA CONCENTRATION AT GALT STP

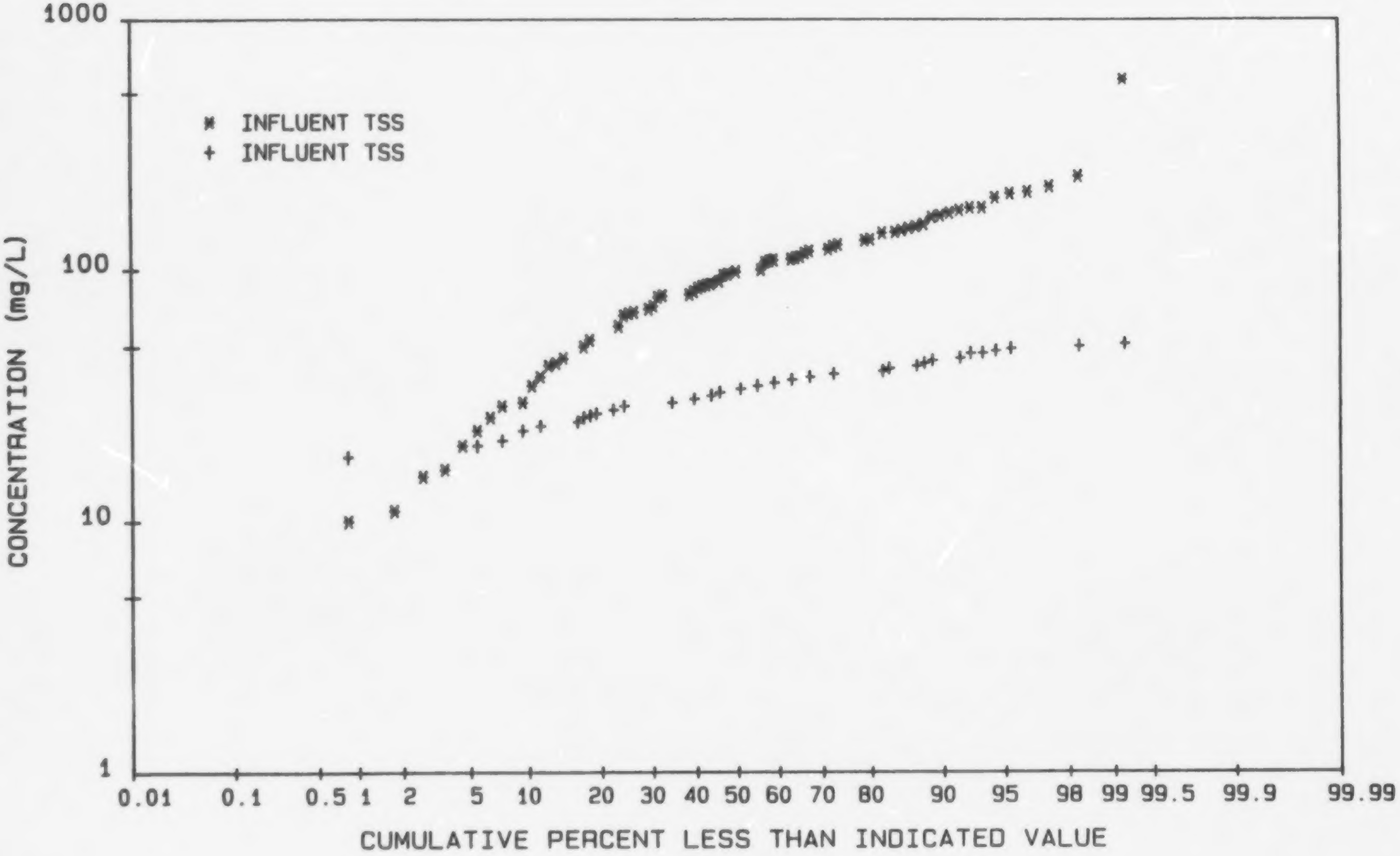


FIGURE 83 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TSS CONCENTRATION AT GALT STP

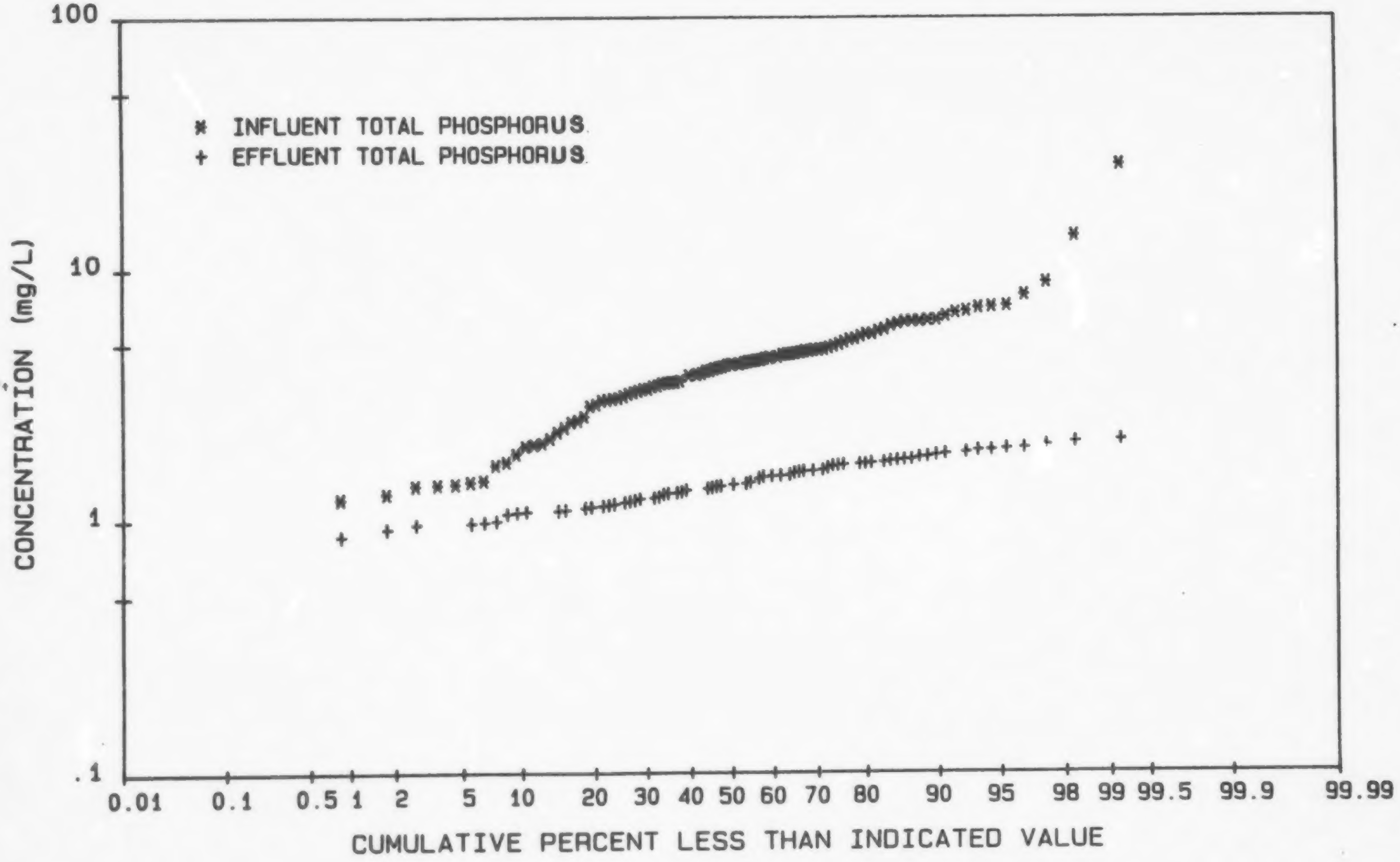


FIGURE 84 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOTAL PHOSPHORUS CONCENTRATION AT GALT STP

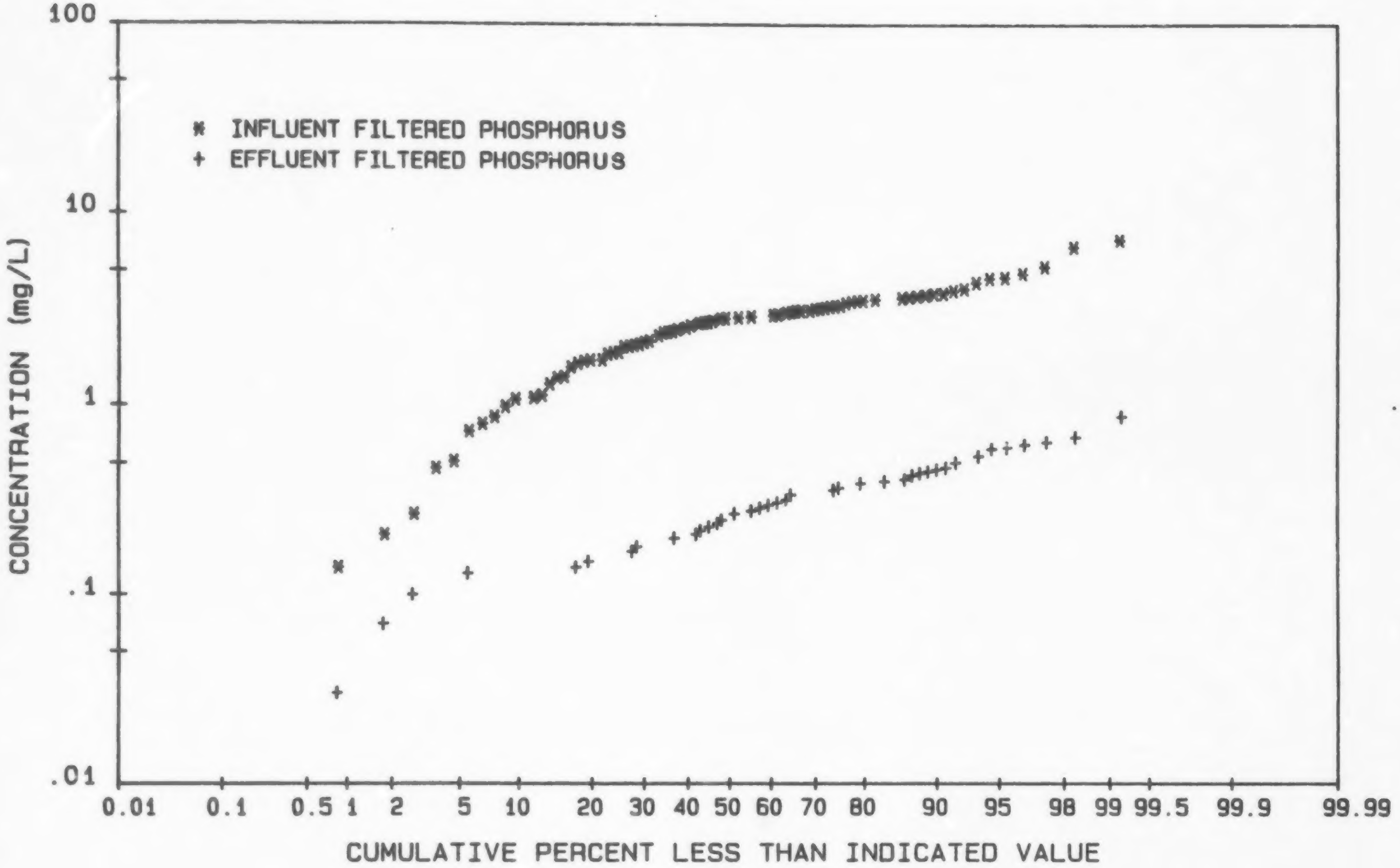


FIGURE 85 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FILTERED PHOSPHORUS CONCENTRATION AT GALT STP

Table 50
CONVENTIONAL CONTAMINANT DATA FOR GALT STP

	Influent						Effluent					
Parameter*	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	n	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
BOD_5	6	62.8	76.5	46.1	60.3	-	6	14.8	16.3	6.1	37.4	-
FOC	99	46.8	51.0	19.0	37.2	82.5	99	16.2	16.5	8.8	53.3	22.1
TSS	99	84.6	102.	66.6	65.3	201.	99	33.2	34.2	7.9	23.1	48.6
TP	99	3.9	4.4	2.9	65.9	7.4	99	1.4	1.4	0.3	21.4	1.9
Filt. P	99	2.2	2.6	1.2	46.2	4.5	99	0.25	0.29	0.15	51.7	0.6
TKN	50	19.7	20.9	7.1	34.0	-	8	15.6	15.7	1.3	8.0	-
NH_3-N	9	11.4	11.9	3.5	29.4	-	50	9.7	11.4	3.9	34.2	-

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*All concentrations reported in mg/L. RSD reported in %.

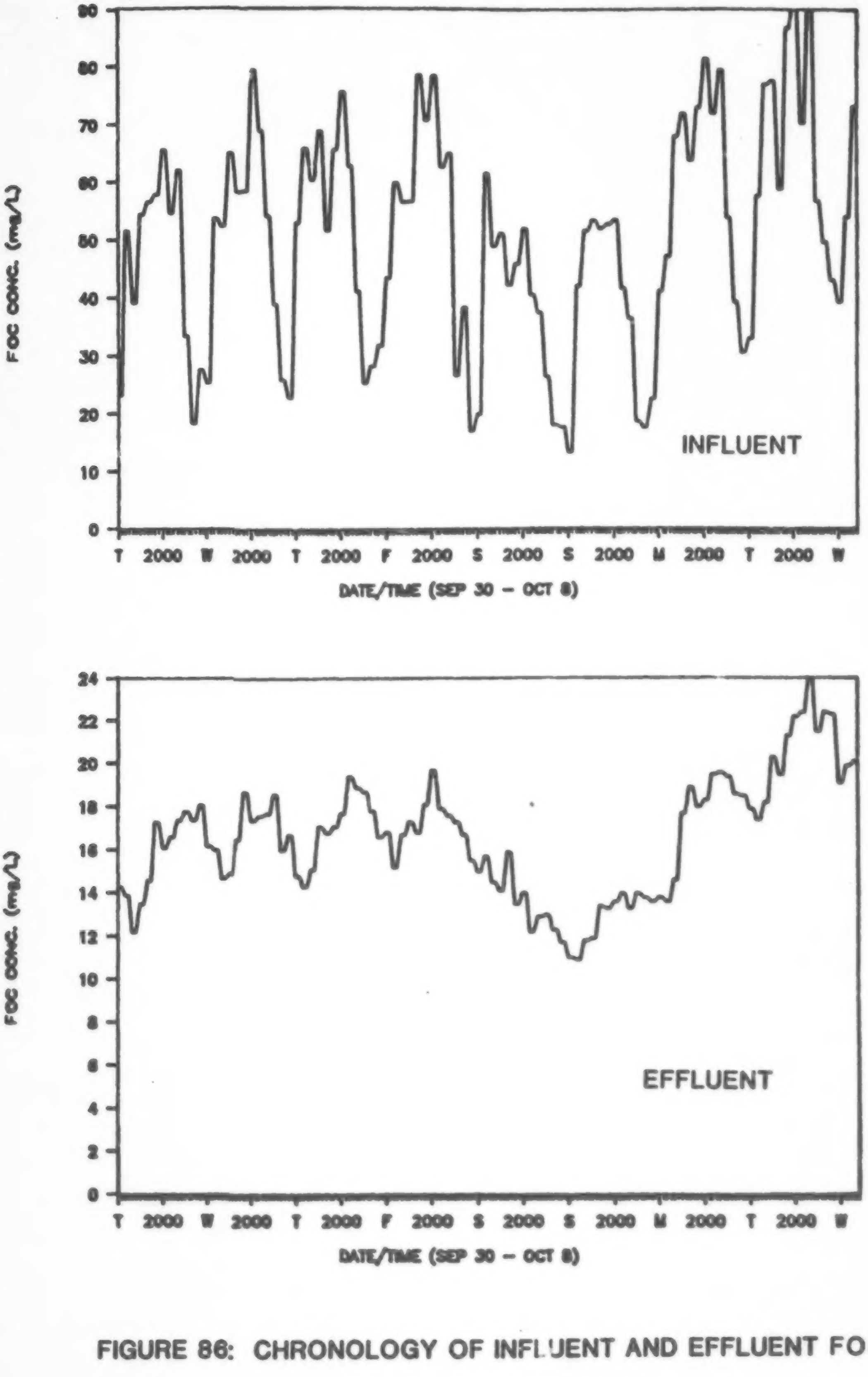
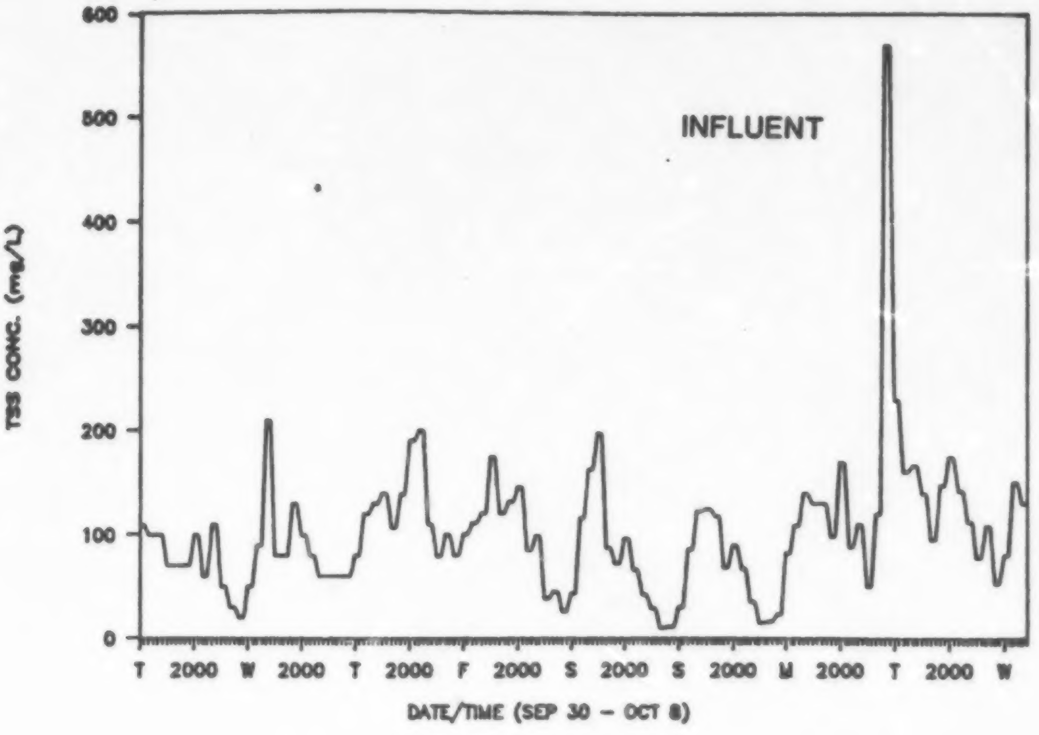


FIGURE 86: CHRONOLOGY OF INFLUENT AND EFFLUENT FOC AT GALT WPCP



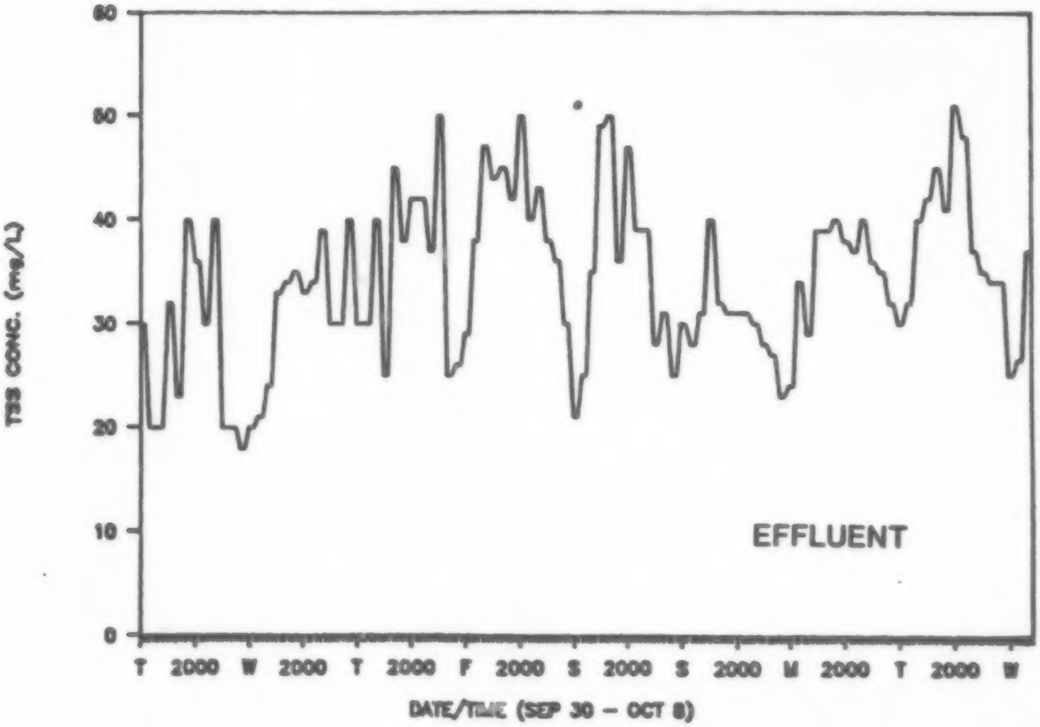
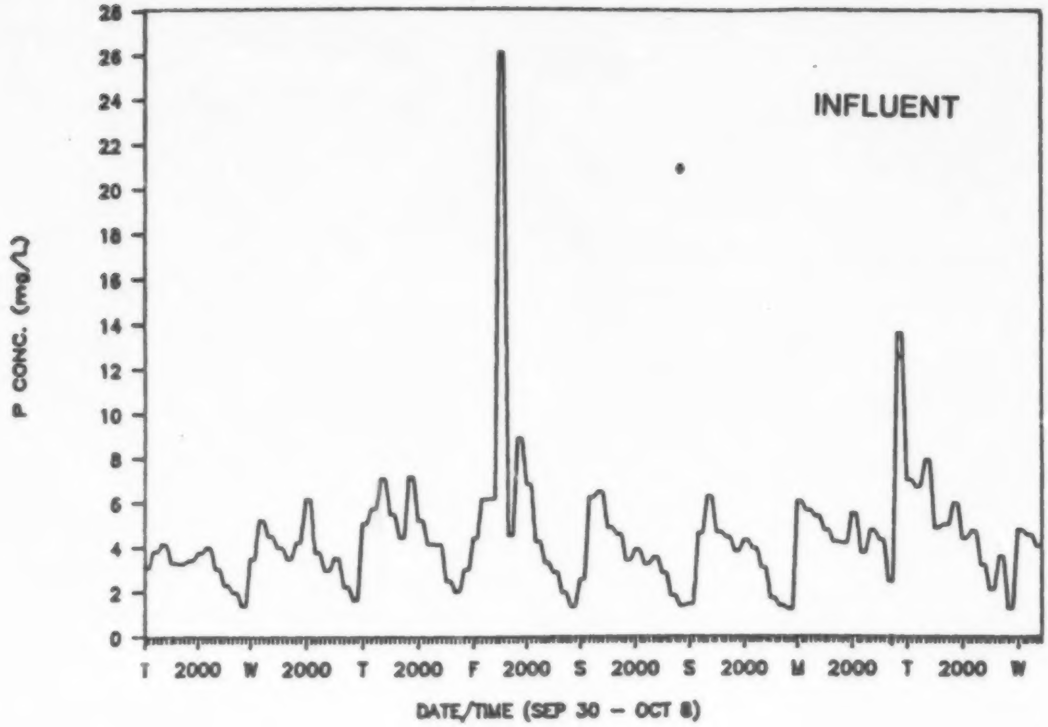


FIGURE 87: CHRONOLOGY OF INFLUENT AND EFFLUENT TSS AT GALT WPCP



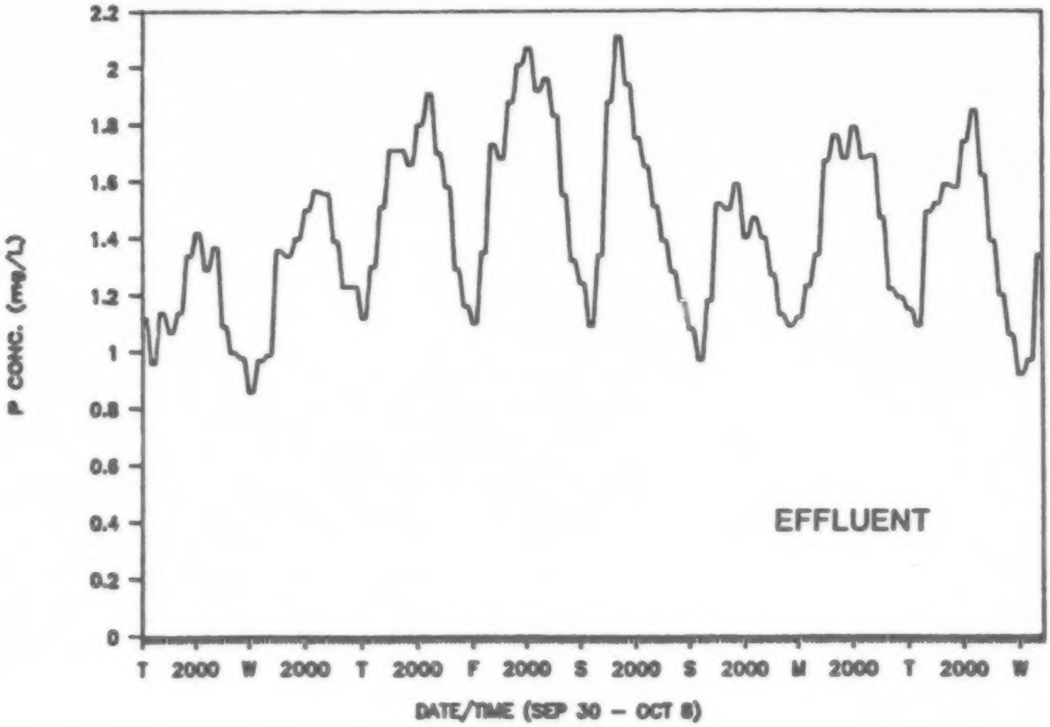
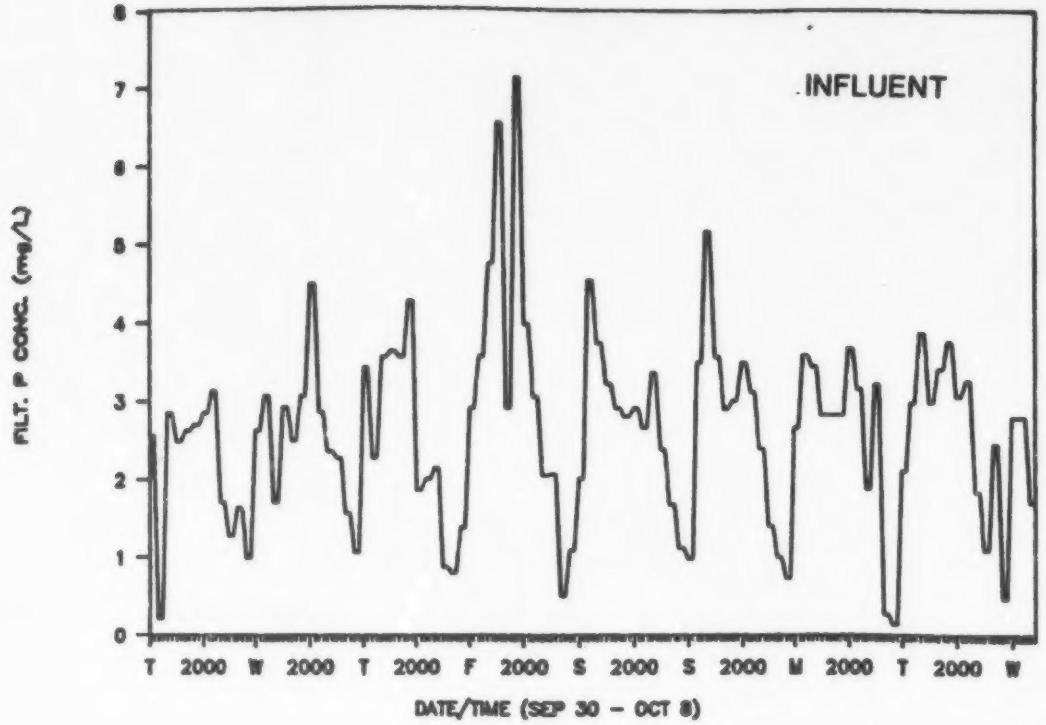


FIGURE 88: CHRONOLOGY OF INFLUENT AND EFFLUENT P AT GALT WPCP



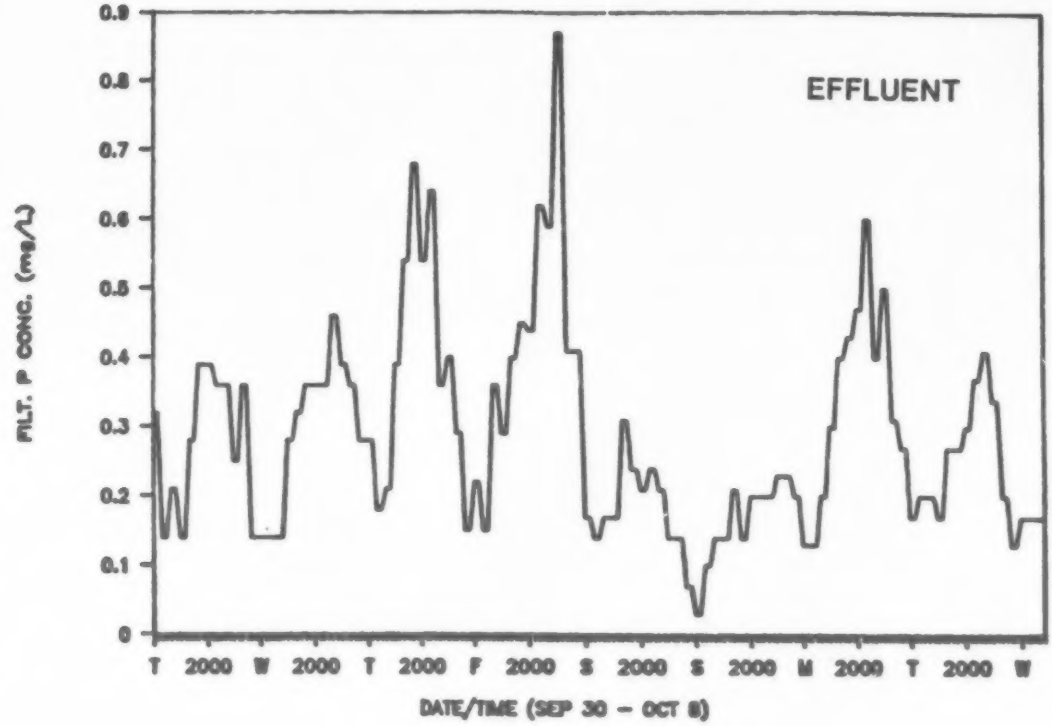


FIGURE 89: CHRONOLOGY OF INFLUENT AND EFFLUENT FILT. P
AT GALT WPCP

cause of the extreme influent TP concentration on October 3 is unknown. Filtered phosphorus showed a lesser but significant peak at the same time.

5.2.2 Metals

Probability distributions for influent and effluent concentrations of cadmium, chromium, copper, nickel, lead and zinc are presented in Figures 90 to 95, respectively. Key statistics describing these distributions are summarized in Table 51.

As was observed at Waterloo and Welland, copper and zinc were present at the highest levels in the Galt STP influent. Concentration ranges for metals in Galt STP raw sewage were consistent with those at Waterloo with copper and zinc exceeding 100 µg/L, chromium, lead and nickel in the 10 to 60 µg/L range and cadmium at the lowest concentration (less than 5 µg/L). Metal concentrations were consistently higher at Galt than had been observed at Welland.

Chronological plots of influent and effluent metal concentrations at the Galt STP are shown in Figures 96 to 101. As identified at the other sampling sites, the metal species exhibited markedly different behaviour. Influent cadmium concentrations (Figure 96) did not exhibit a significant diurnal trend but two extreme peaks were evident in the influent data at the end of the monitoring period. Influent concentrations during these events were near 60 µg/L compared to an overall geometric mean of 3.5 µg/L. Neither of these major peaks were associated with the accidental return of supernatant to the headworks, although a third lower peak to a concentration of about 10 µg/L was identified at the time of supernatant return to the influent works. Effluent cadmium concentrations were at near detection limit levels and the lack of resolution of the analytical method precluded identification of any significant diurnal pattern. There was a significant peak to near 10 µg/L in the effluent which appeared to be correlated to the initial peak in the influent concentration. An increase in the effluent concentration to about 4 µg/L at the end of the monitoring period also suggests an influent/effluent relationship which was shown to be statistically significant based on the cross-correlation function at a lag time of 10 to 14 hours.

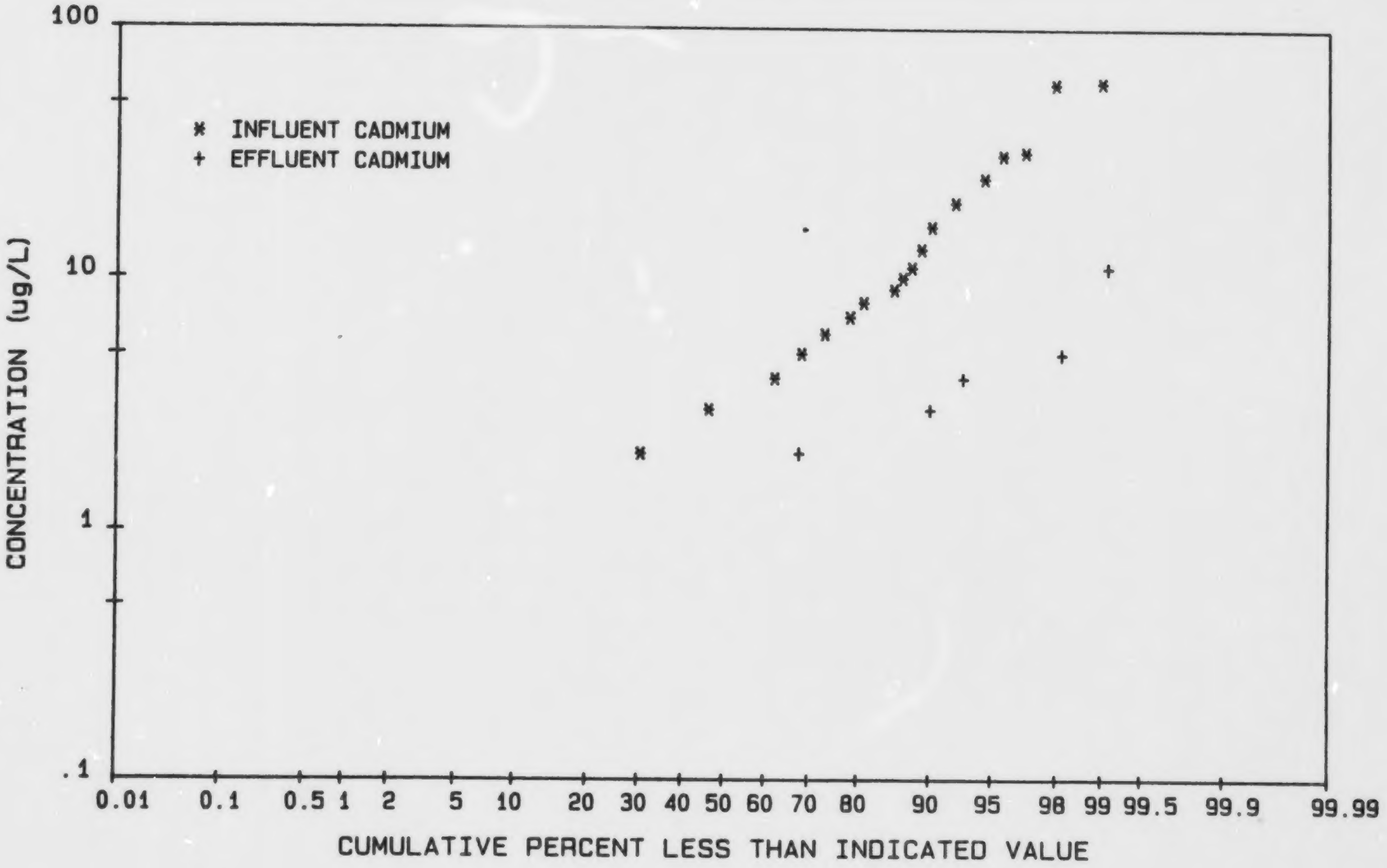


FIGURE 90 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CADMIUM CONCENTRATION AT GALT STP

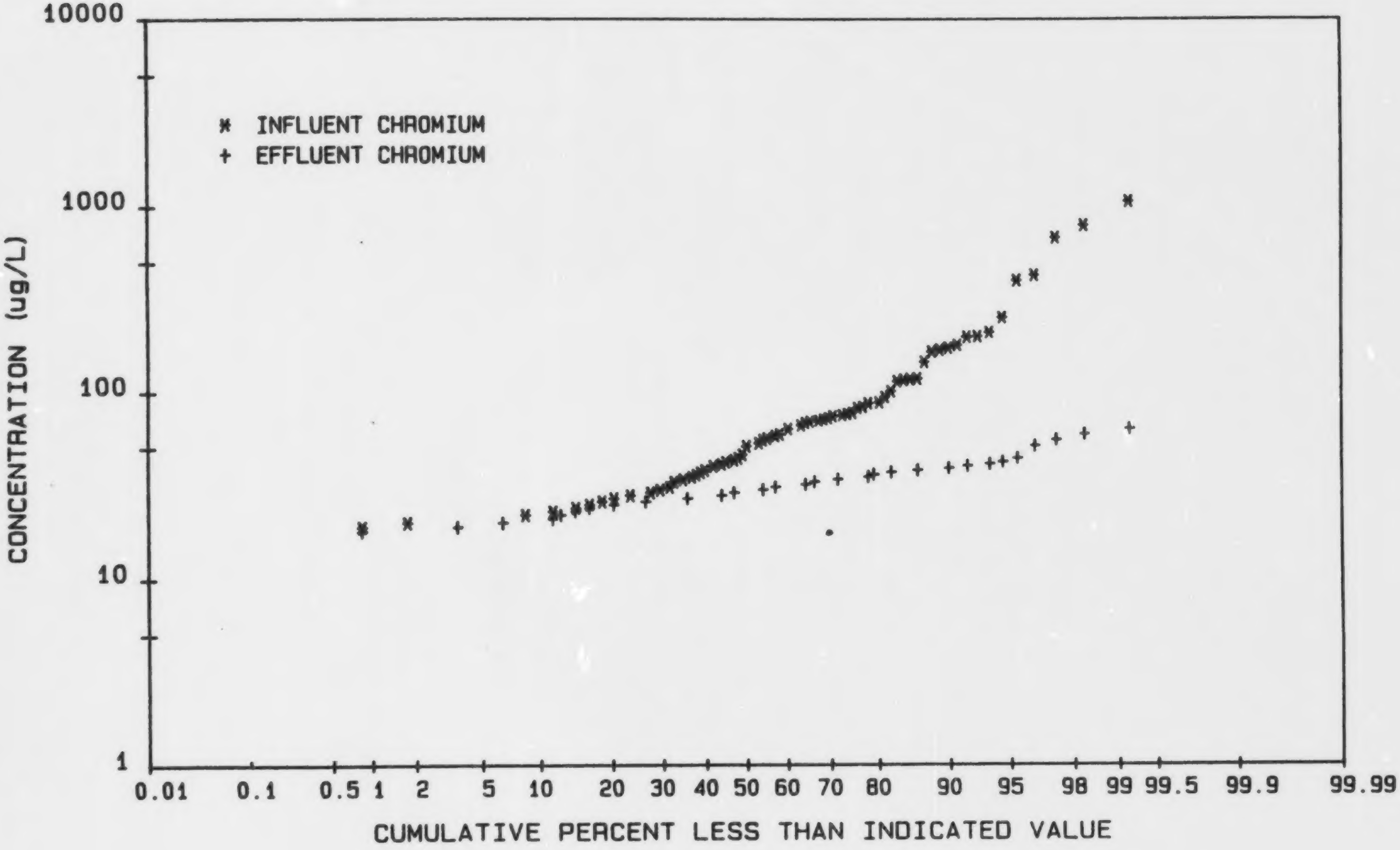


FIGURE 91 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHROMIUM CONCENTRATION AT GALT STP

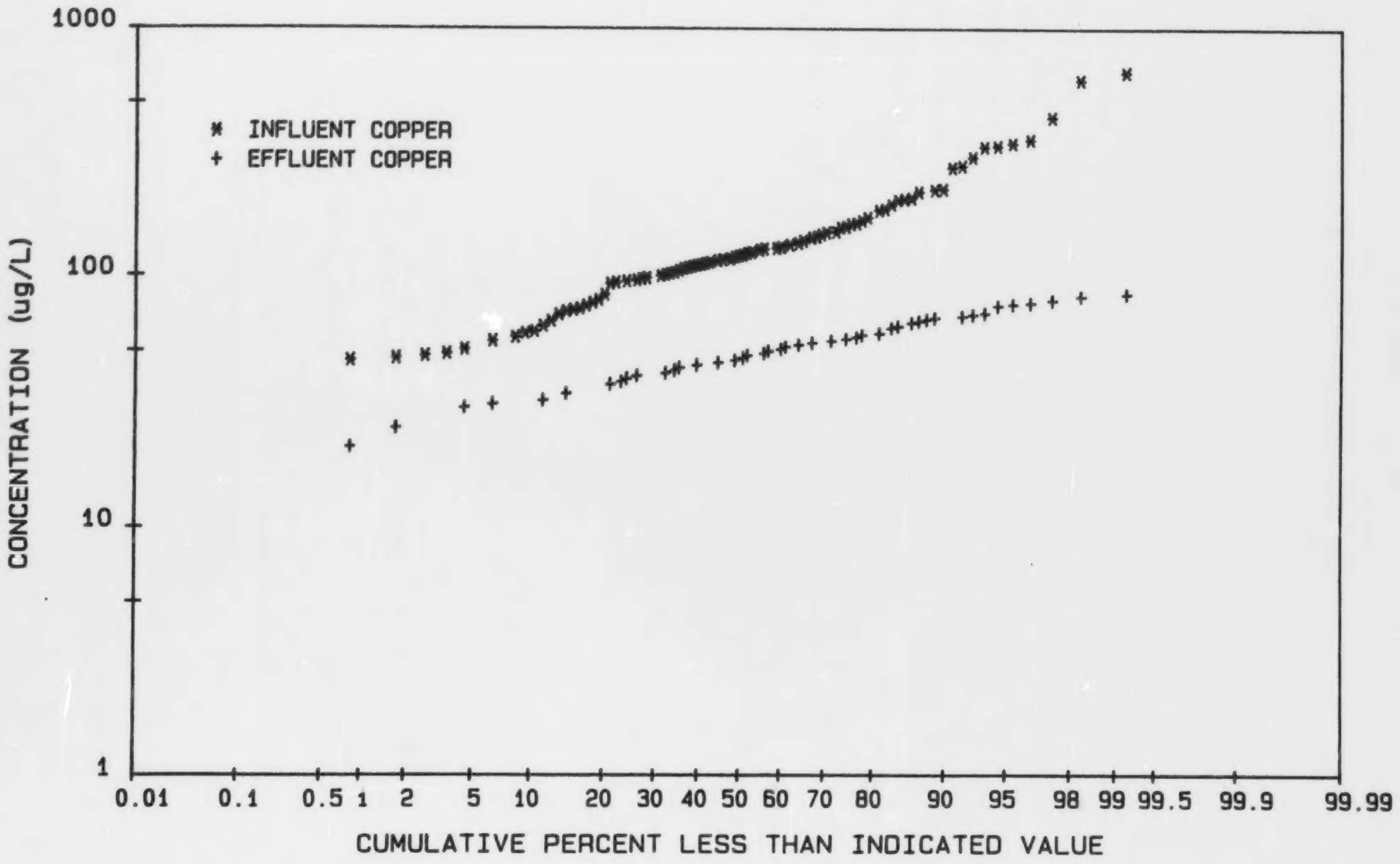


FIGURE 92 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT COPPER CONCENTRATION AT GALT STP

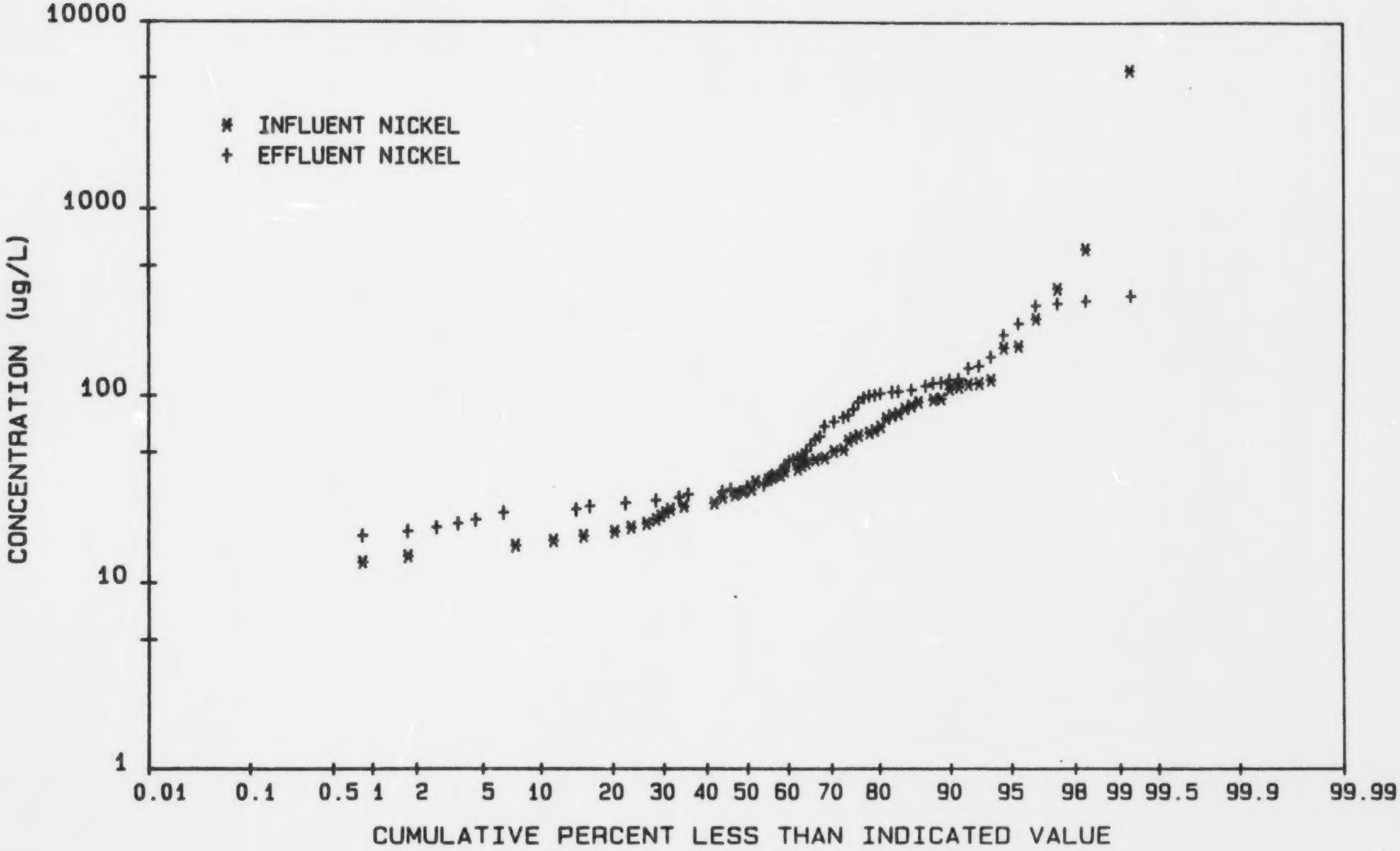


FIGURE 93 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT NICKEL CONCENTRATION AT GALT STP

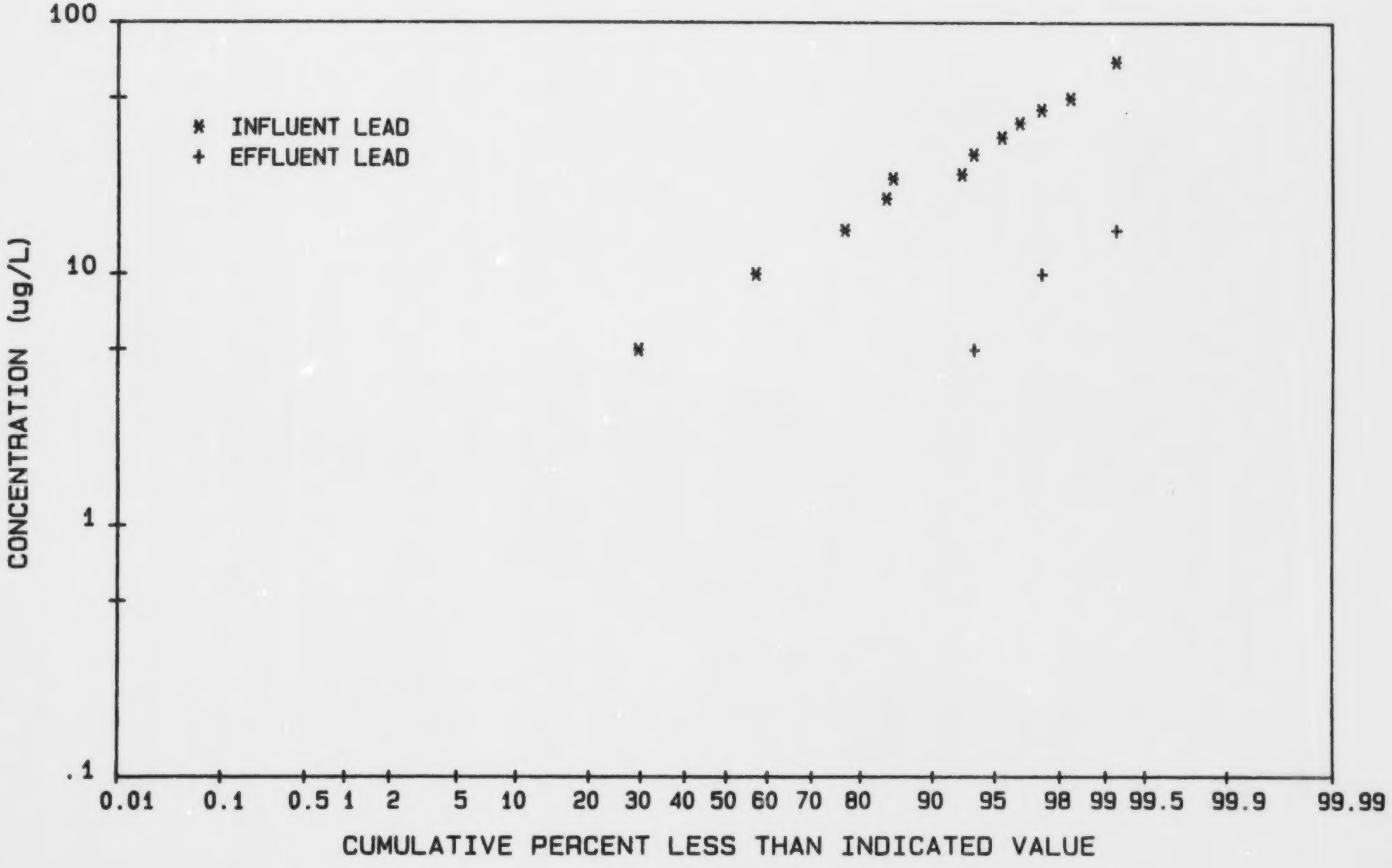


FIGURE 94 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT LEAD CONCENTRATION AT GALT STP

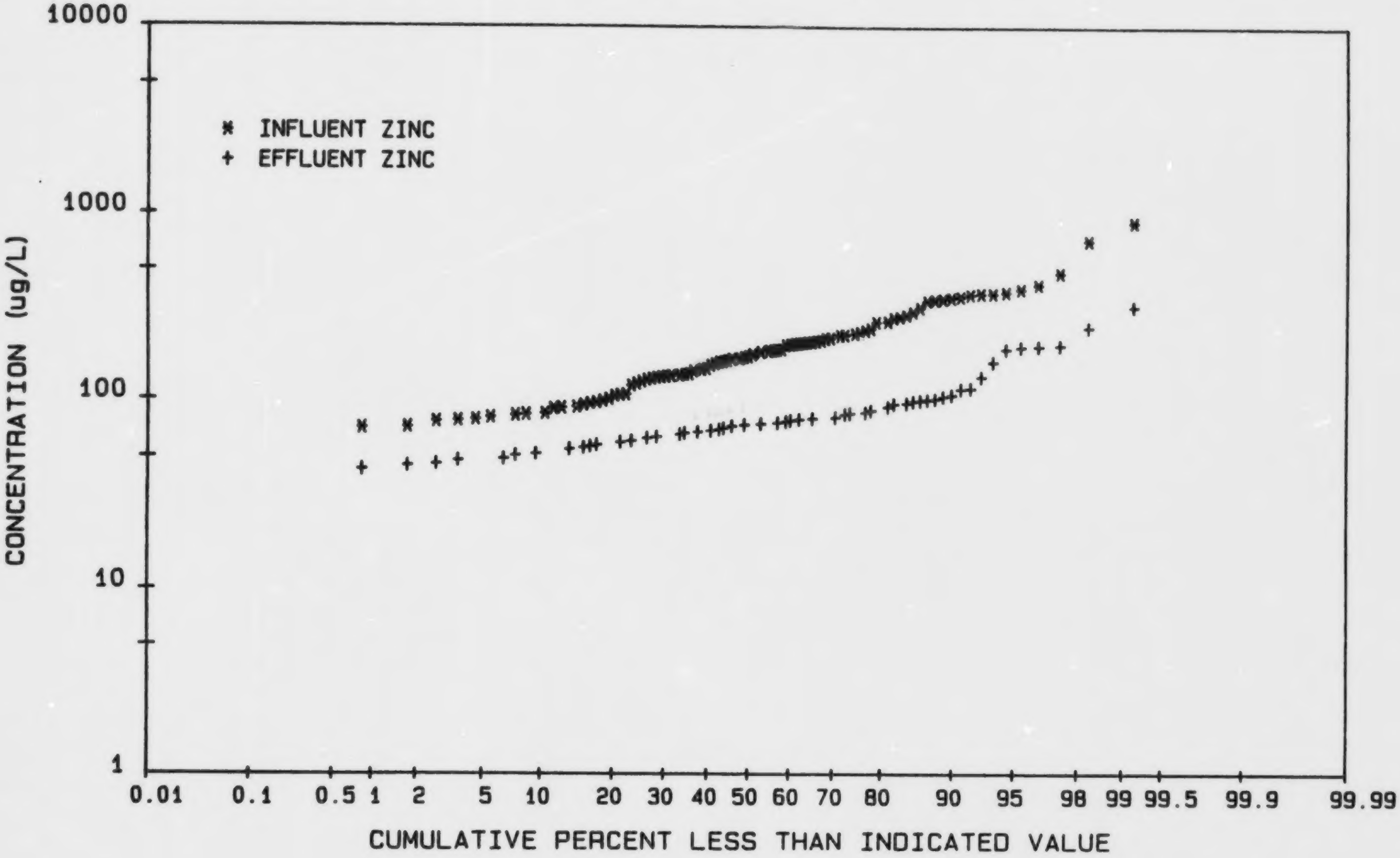


FIGURE 95 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT ZINC CONCENTRATION AT GALT STP

Table 51
METAL CONCENTRATION DATA FOR GALT STP

	Influent**					Effluent**				
Parameter*	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Cadmum	3.5	6.2	9.8	158.	27.4	2.2	2.4	1.2	50.0	5.0
Chromium	56.3	92.8	150.	162.	283.	30.1	31.0	8.1	26.1	44.8
Copper	125.	146.	102.	69.9	326.	47.3	49.2	13.6	27.6	77.2
Nickel	40.1	111.	550.	495.	671.	48.1	66.6	67.8	102.	225.
Lead	11.1	13.9	10.7	76.9	34.9	5.3	5.4	1.7	31.5	7.6
Zinc	172.	199.	126.	64.8	384.	77.2	83.2	40.5	48.7	186.

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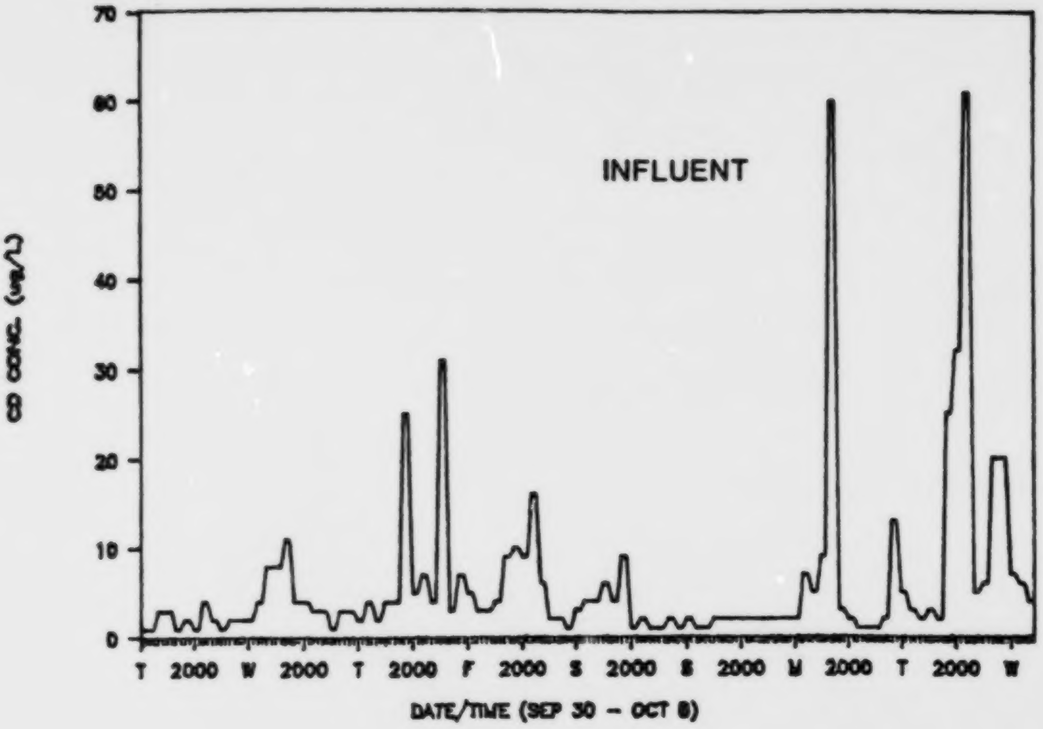
*All concentrations reported in µg/L. RSD reported in %.
**Based on 99 samples.



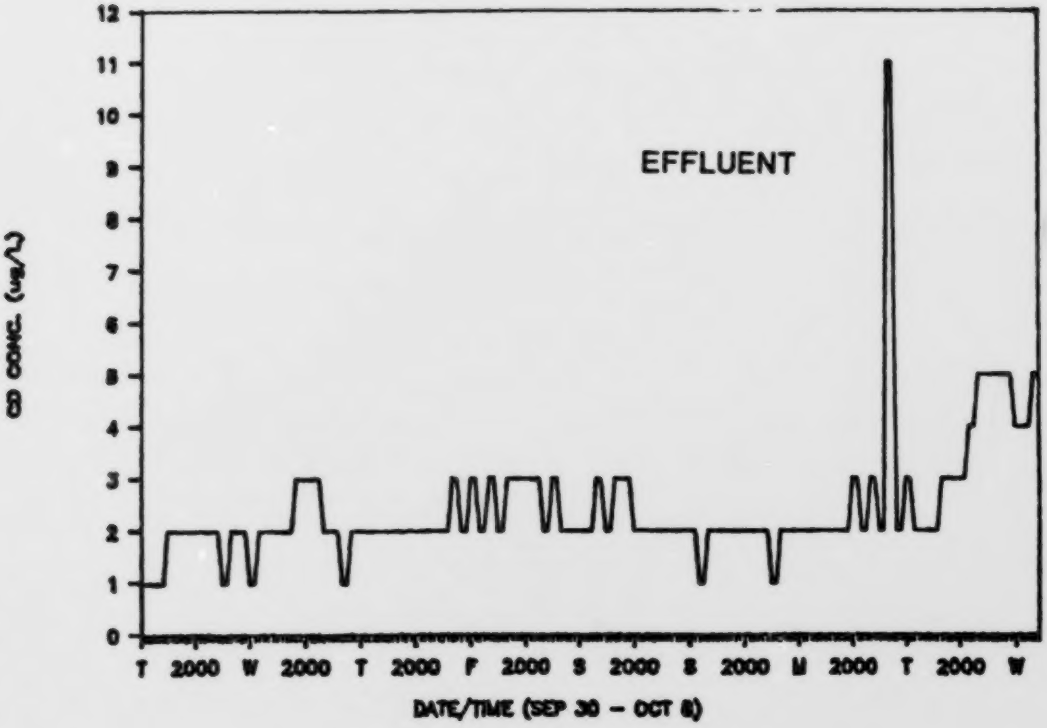
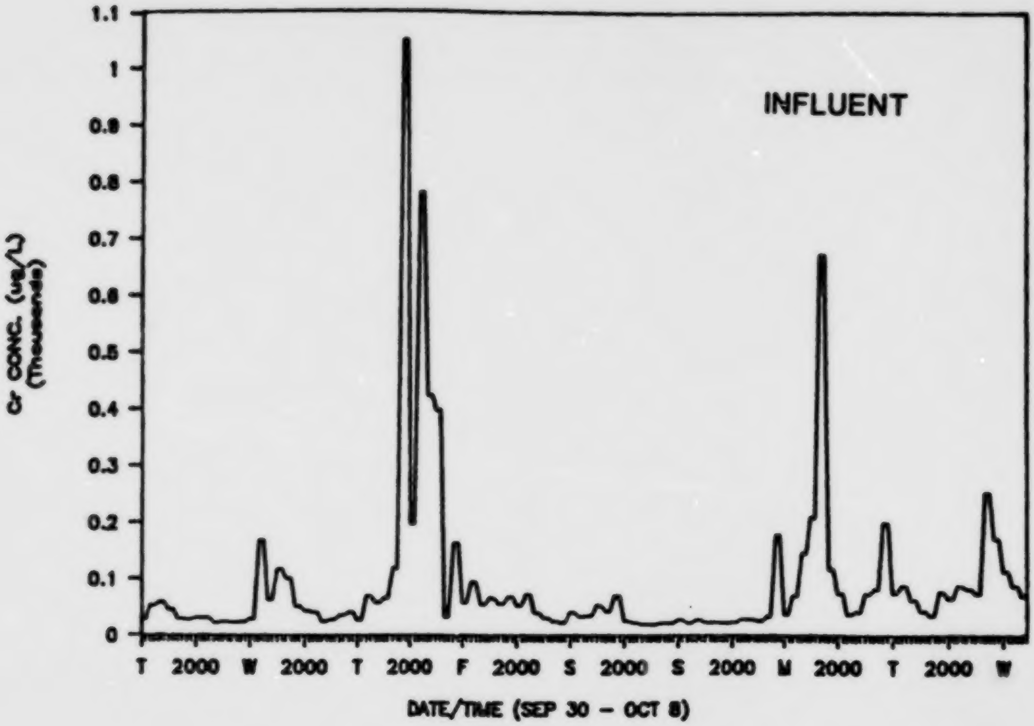


FIGURE 96: CHRONOLOGY OF INFLUENT AND EFFLUENT Cd AT GALT WPCP



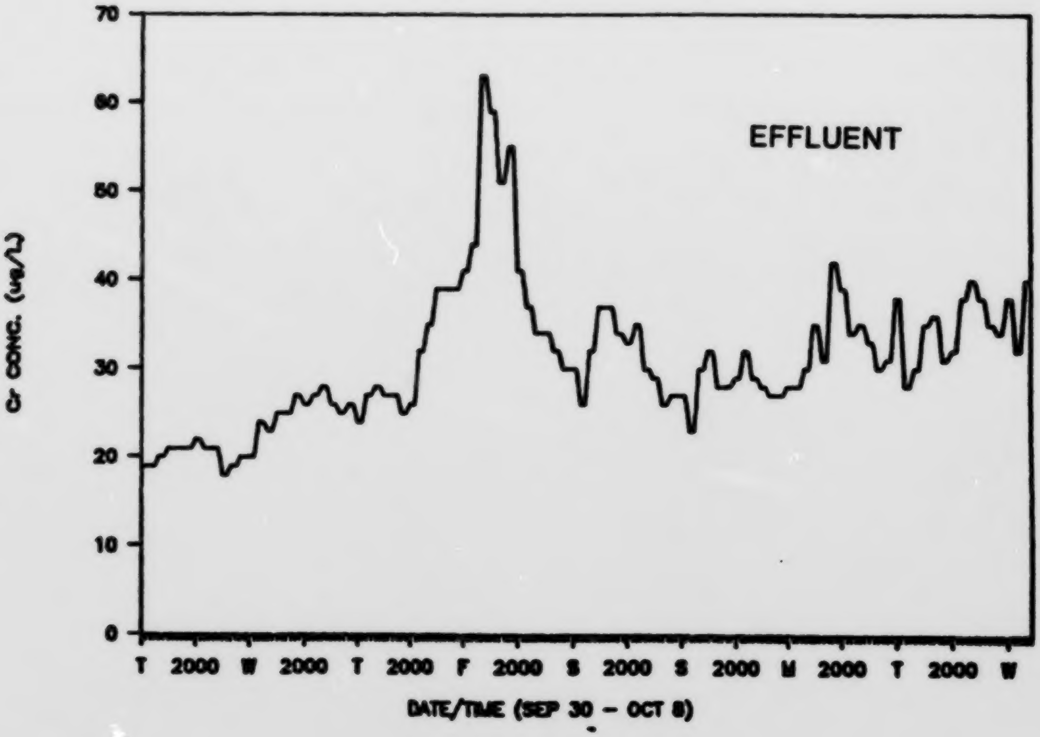


FIGURE 97: CHRONOLOGY OF INFLUENT AND EFFLUENT Cr AT GALT WPCP

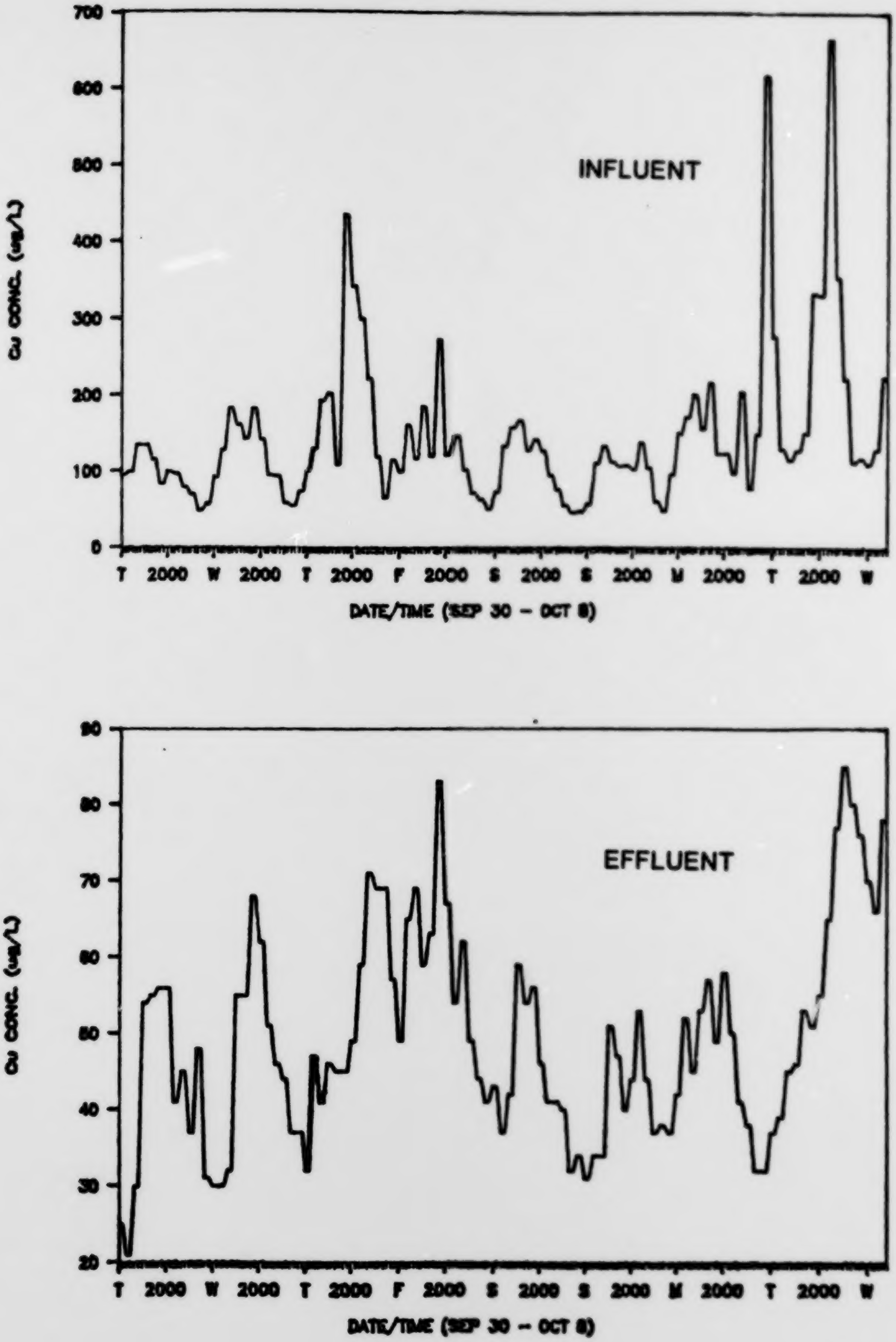
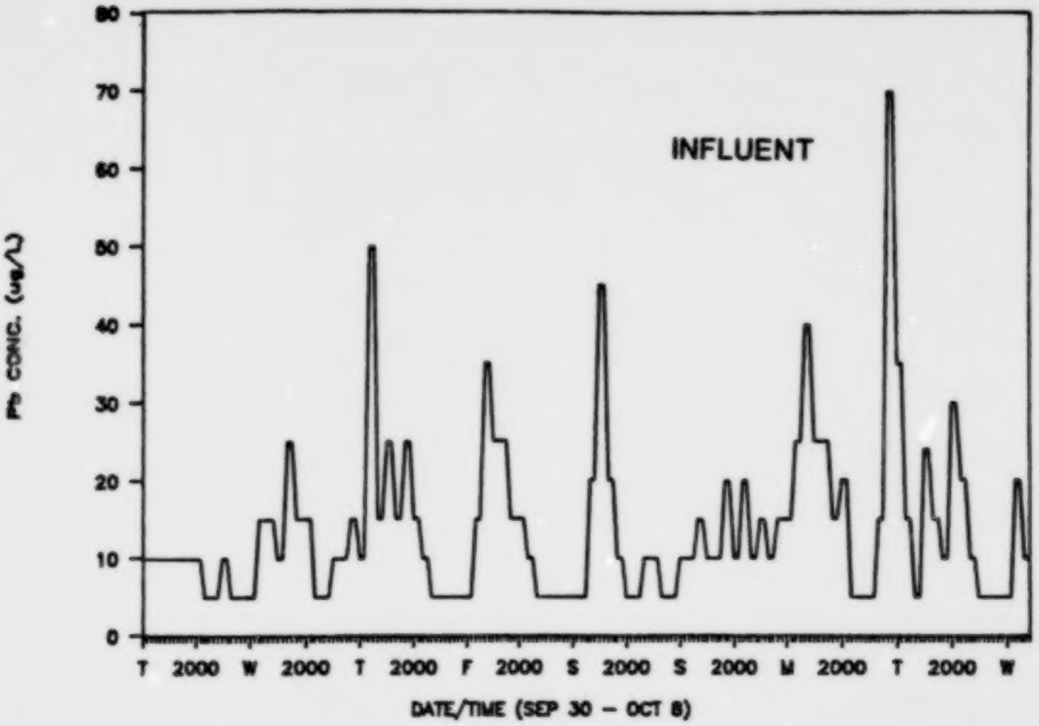


FIGURE 98: CHRONOLOGY OF INFLUENT AND EFFLUENT Cu AT GALT WPCP



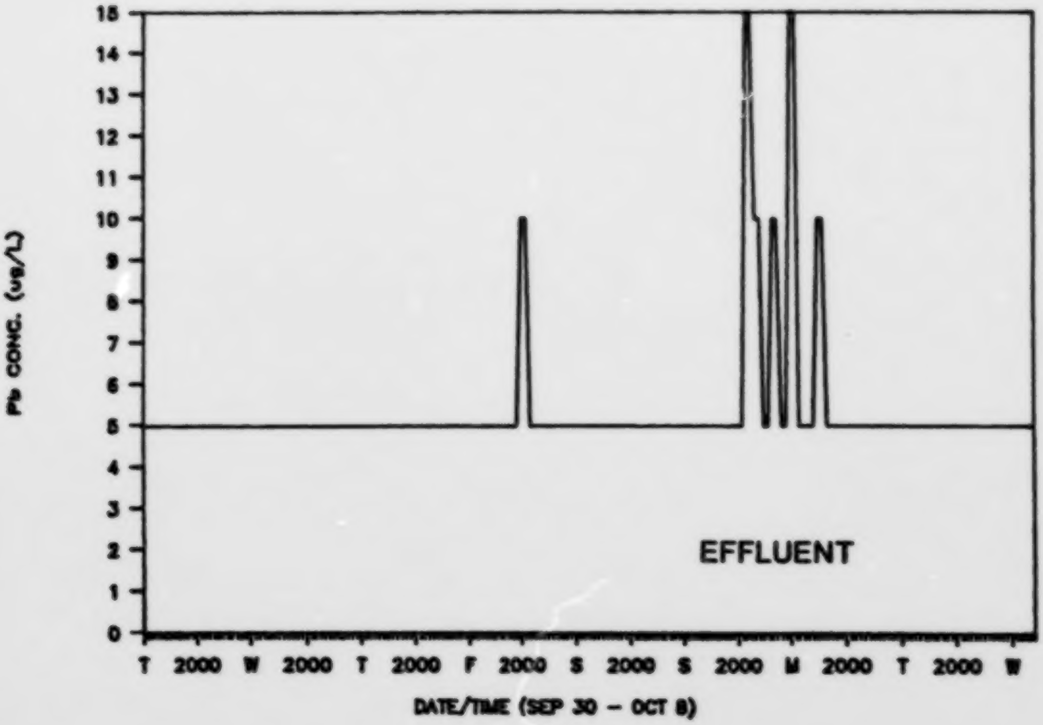


FIGURE 99: CHRONOLOGY OF INFLUENT AND EFFLUENT Pb AT GALT WPCP

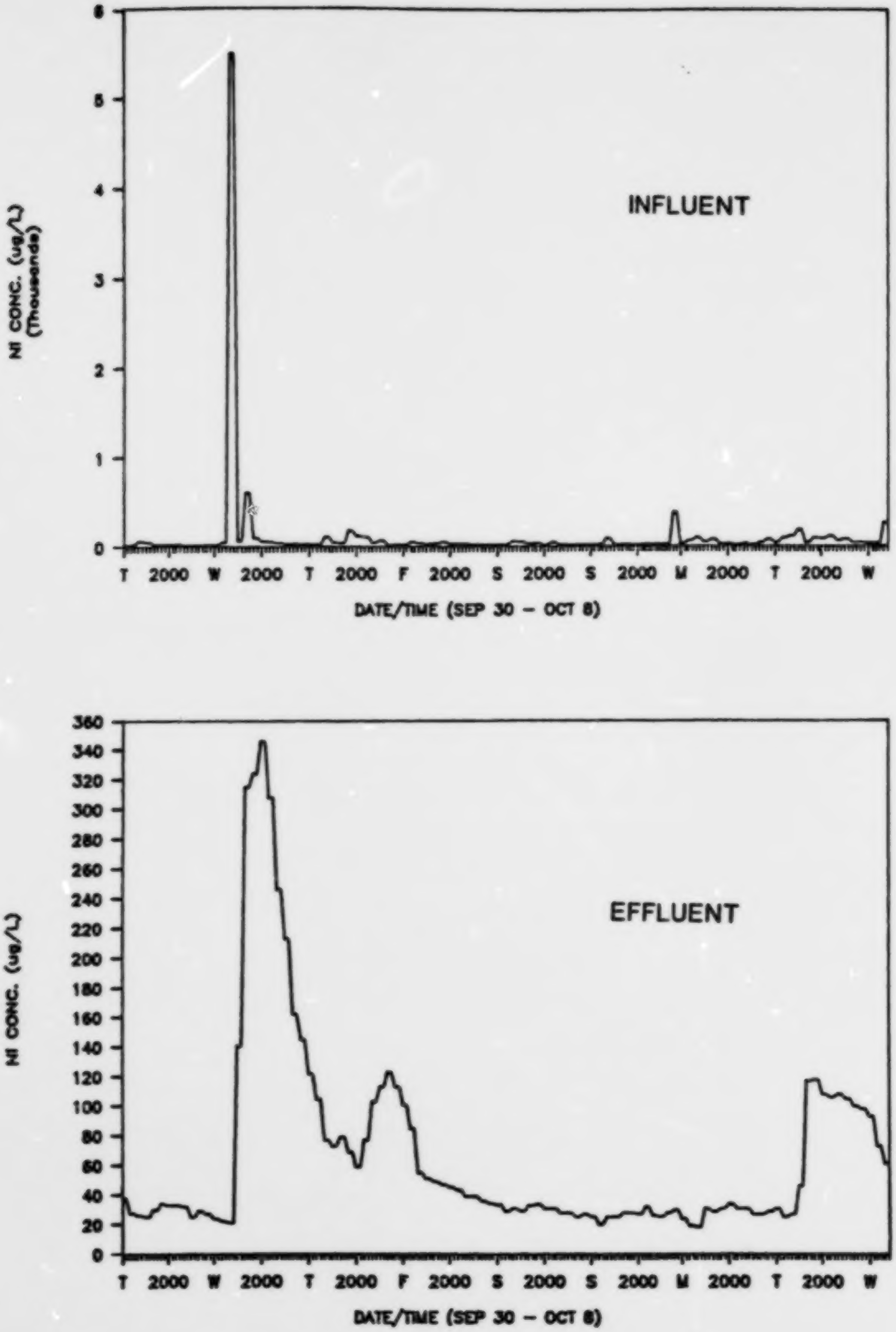


FIGURE 100: CHRONOLOGY OF INFLUENT AND EFFLUENT Ni AT GALT WPCP

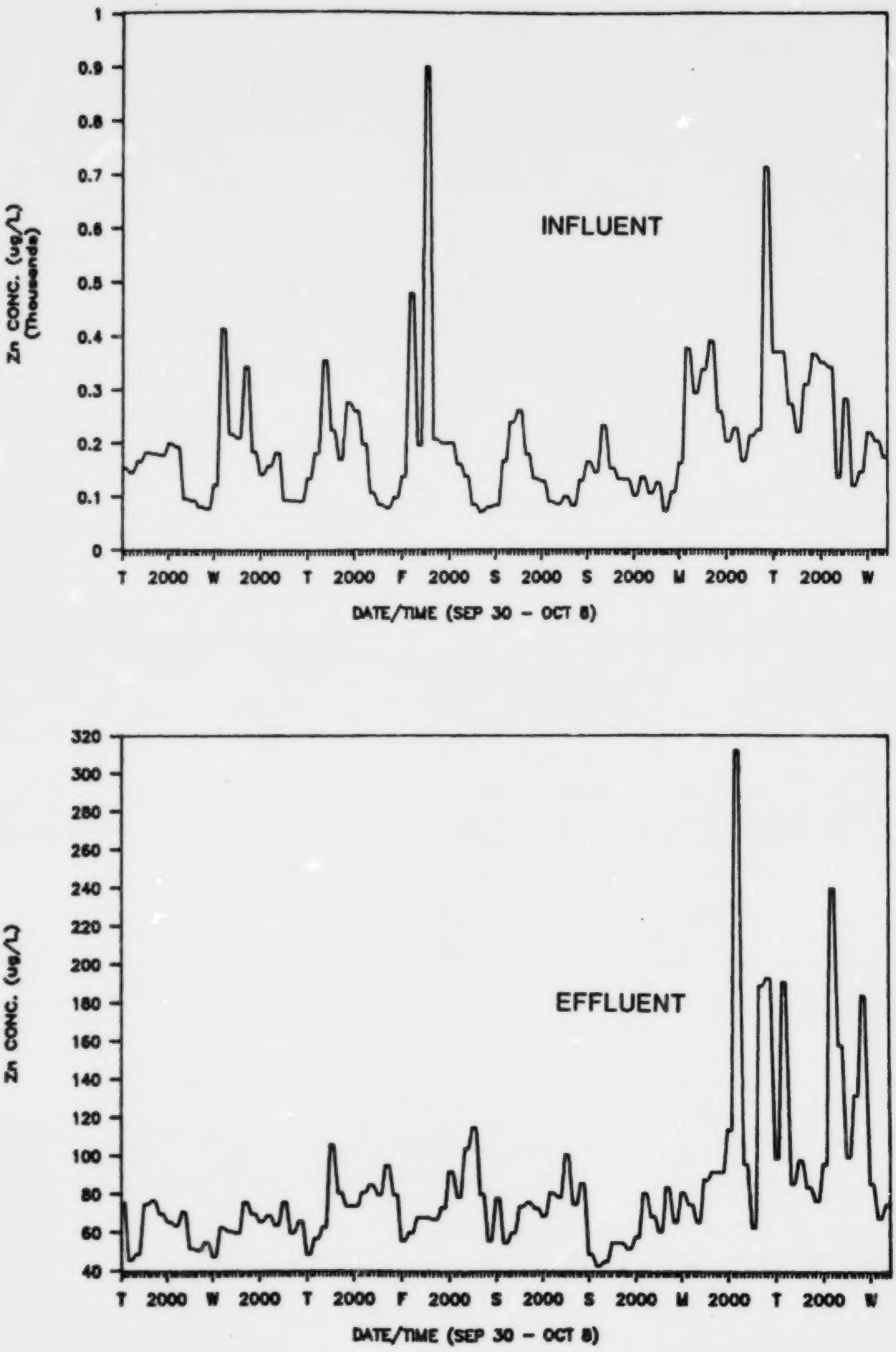


FIGURE 101: CHRONOLOGY OF INFLUENT AND EFFLUENT Zn AT GALT WPCP

During the latter period of the monitoring program, chromium influent concentration data (Figure 97) suggest a diurnal pattern; however, this pattern was not statistically significant based on the autocorrelation of the influent sequence. Several major influent perturbations were evident, with the highest concentration exceeding 1 mg/L. Effluent concentrations were high enough compared to the detection limit that a significant correlation between the influent and effluent data was identifiable at a lag time in the order of 18 hours. No diurnal pattern in the effluent was identifiable.

The chronological influent copper sequence (Figure 98) suggest a diurnal sequence; however, statistically this pattern was not significant. The high peak concentrations identified at the end of the monitoring period may have influenced the autocorrelation function. The first of these peak concentrations occurred at the time of supernatant return to the headworks and may have been related to that event. The second peak was unrelated to supernatant return. The effluent copper concentration sequence was significantly correlated to the influent sequence but did not exhibit a diurnal trend.

The raw sewage nickel concentration sequence (Figure 99) was dominated by a peak concentration exceeding 5 mg/L early in the monitoring period. The plant effluent sequence showed a "wash out" curve in response to the influent peak, lagging the influent perturbation by about 4 to 6 hours.

Lead concentrations in influents and effluents (Figure 100) were near detection limits and the lack of resolution of the analytical methods at this concentration precluded identification of any significant pattern in these sequences.

Influent and effluent zinc concentration data (Figure 101) showed a significant diurnal pattern and a significant cross-correlation. The impact of the accidental return of digester supernatant on the influent zinc concentration was apparent on October 7. The effluent concentration sequence exhibited significantly greater variability at the end of the monitoring period than at the start despite similar variability in the influent zinc levels.

Average removal efficiencies for the metal species are summarized in Table 52. With the exception of cadmium and nickel, heavy metal removals at the Galt STP were generally consistent with those at the Waterloo and Welland STPs. Cadmium removals were considerably higher at Galt and probably more representative of removals achievable when quantifiable influent concentrations are experienced at a municipal STP. The nickel removal data are skewed by the extreme influent peak experienced during the period. The geometric mean effluent nickel calculated for the Galt STP actually exceeded in the influent concentration during the monitoring period although the calculated removal efficiency was 40 percent based on the arithmetic mean concentrations.

Table 52
REMOVAL OF HEAVY METALS IN GALT STP

Metal	Removal (Percent) Based on Arithmetic Mean	 Geometric Mean
Cadmium	61.3	37.1
Chromium	66.5	46.5
Copper	66.3	62.2
Nickel	40.0	-
Lead	61.2	52.2
Zinc	58.2	55.1

5.2.3 Trace Organics

5.2.3.1 Phenolics

Probability distributions of influent and effluent total phenolics concentrations are presented in Figure 102 for the Galt STP. The geometric mean influent concentration was 19.9 μg/L (arithmetic mean concentration 23.6 μg/L; RSD = 54.2 percent) comparable to the concentration identified at Waterloo or Welland. The Galt STP effluent phenolics concentration averaged 3.5 μg/L, based on the geometric mean (arithmetic mean 4.3 μg/L; RSD = 60 percent), indicating a removal efficiency of approximately 82 percent.

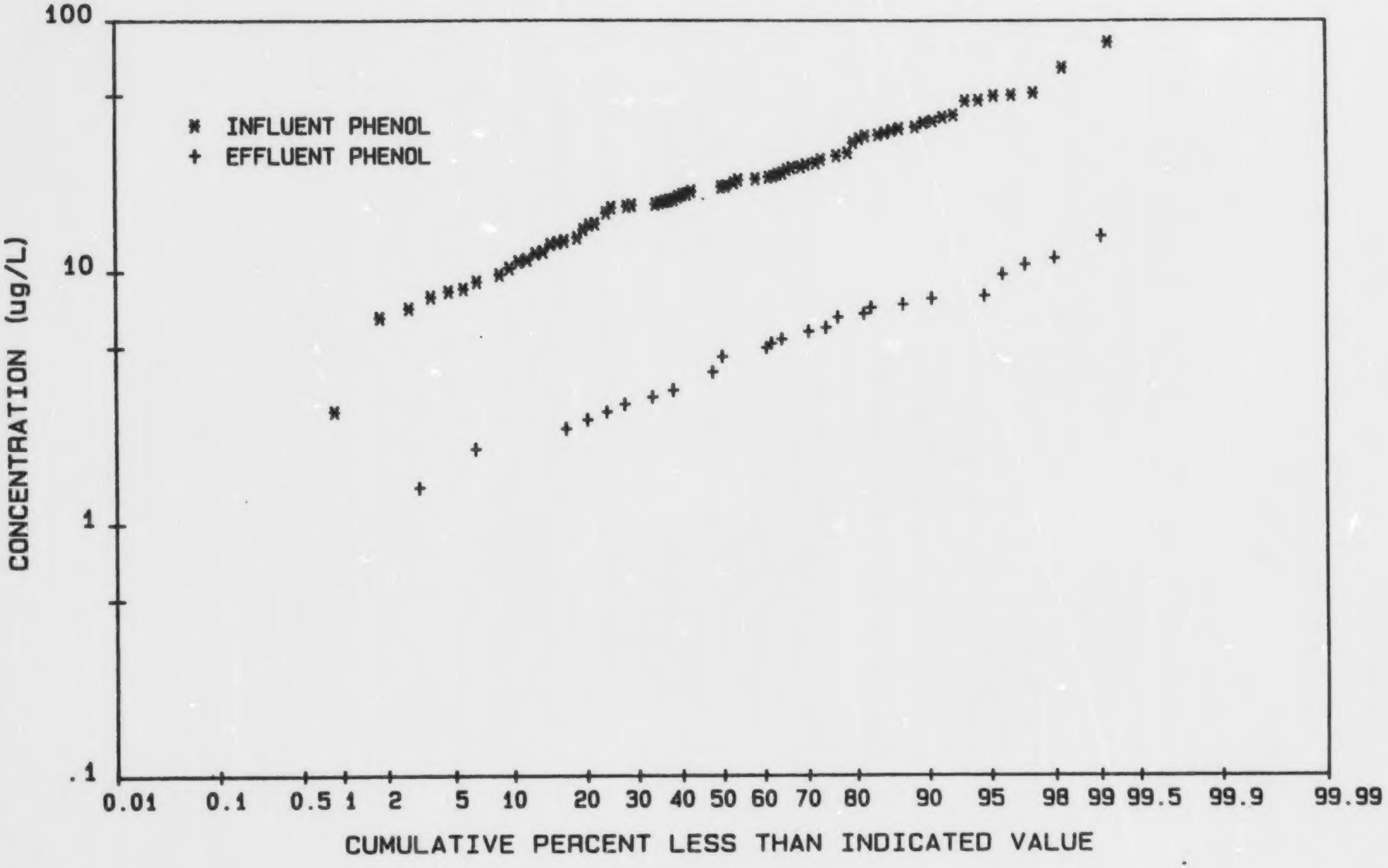


FIGURE 102 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOTAL PHENOL CONCENTRATION AT GALT STP

The chronology of influent and effluent total phenols concentration data is presented in Figure 103. The influent sequence exhibited a slight but significant diurnal trend but the effluent sequence was random in nature.

5.2.3.2 Volatile Organics

Table 53 summarizes the frequency of detection (FOD) of selected chlorinated and non-chlorinated organics in the raw sewage and the secondary effluent from the Galt STP.

Table 53
FREQUENCY OF DETECTION OF VOLATILE ORGANIC CONTAMINANTS AT GALT STP

Compound	MDL (μg/L)	Frequency of Detection* (%) Influent	Frequency of Detection* (%) Effluent
Dichloromethane	1.0	100	100
Chloroform	1.0	78	16
1,2-dichloroethylene	1.0	0	0
1,1,1-trichloroethane	1.0	100	97
Benzene	0.5	77	0
Carbon tetrachloride	1.0	1	0
Bromodichloromethane	1.0	0	0
Trichloroethylene	1.0	100	21
1,1,2-trichloroethane	1.0	0	0
Toluene	0.5	98	3
Dibromochloromethane	1.0	1	0
Tetrachloroethylene	1.0	96	77
Chlorobenzene	0.5	9	0
Ethylbenzene	0.5	84	12
p&m-Xylene	0.5	99	33
Bromoform	1.0	0	0
o-xylene	0.5	97	27
1,1,2,2-tetrachloroethane	1.0	0	0
1,3-dichlorobenzene	1.0	1	1
1,4-dichlorobenzene	1.0	100	91
1,2-dichlorobenzene	1.0	31	18

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*At concentrations above the MDL.

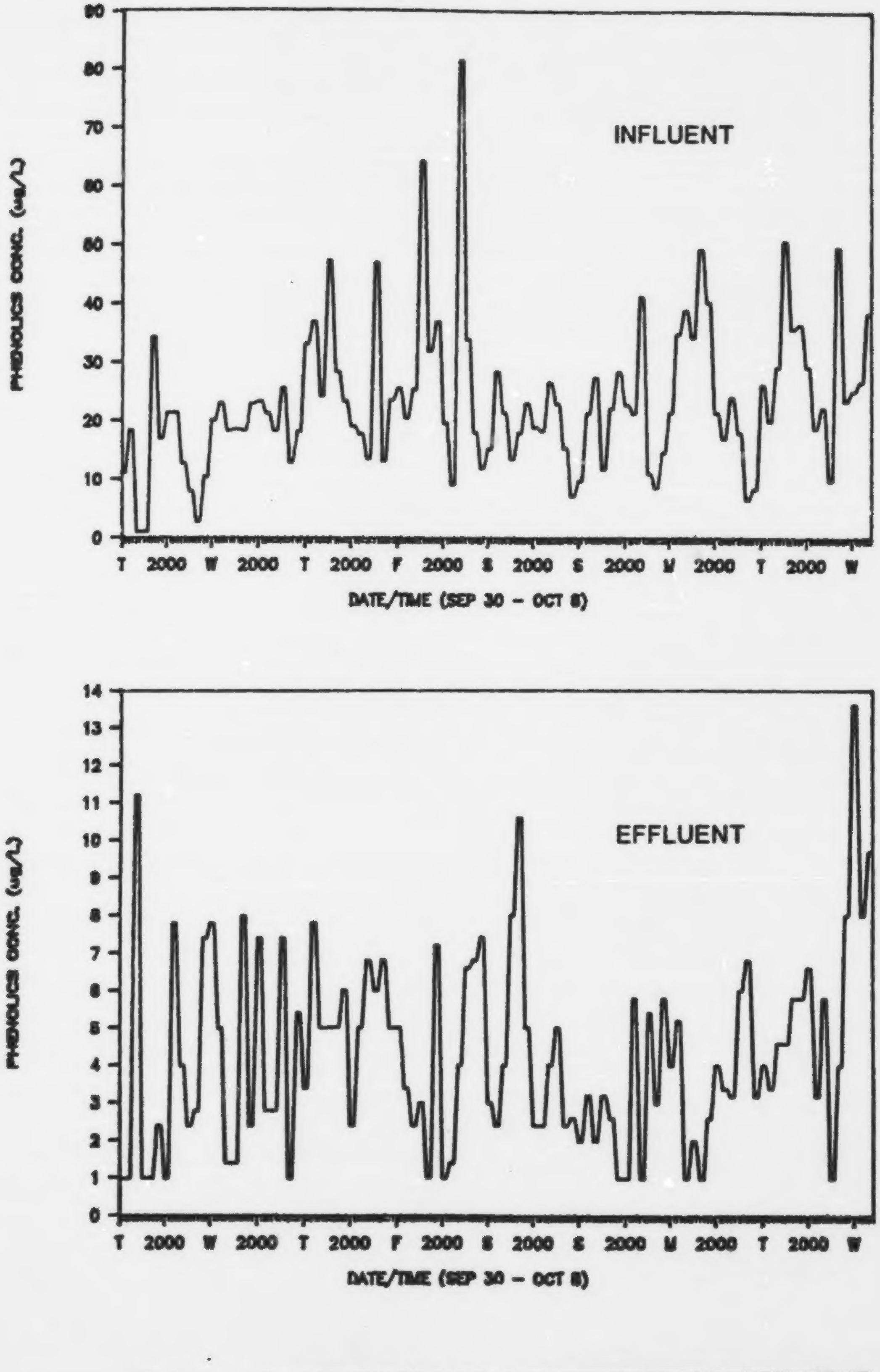

FIGURE 103: CHRONOLOGY OF INFLUENT AND EFFLUENT PHENOLICS AT GALT WPCP

As was the case at the other two STPs, dichloromethane was identified in all influent and effluent samples and further analysis of these data was not undertaken as laboratory contamination was considered to be a factor. Three other chlorinated compounds - 1,1,1-trichloroethane, trichloroethylene and 1,4-dichlorobenzene - were also quantified in all influent samples. In addition, two other chlorinated organics - chloroform and tetrachloroethylene - and five non-chlorinated volatile organics - benzene, toluene, ethylbenzene and the xylene isomers (p&m-xylene and o-xylene) were quantified in more than 50 percent of raw sewage samples. Of these organic compounds, only 1,1,1-trichloroethane, tetrachloroethylene and 1,4-dichlorobenzene were present at concentrations exceeding the MDL in more than 50 percent of the effluent samples. None of the non-chlorinated organics was quantified in more than 50 percent of the effluent samples. Benzene and toluene were almost never detected in effluent samples.

Probability distributions for the volatile organic compounds identified frequently in Galt STP influent samples are presented in Figures 104 through 113. Statistics characterizing these distributions are summarized in Table 54. Chronological plots of the concentrations of these compounds in influents and effluent are shown in Figure 114 through 123.

Influent concentration sequences for organic contaminants at the Galt STP allow a more thorough analysis than those found at the other two STPs because of the generally higher FODs and higher concentrations. However, development of influent-effluent relationships was difficult in most cases because of the low effluent FOD for most contaminants. For example, chloroform (Figure 114) trichloroethylene (Figure 116), toluene (Figure 117), ethylbenzene (Figure 118), benzene (Figure 121) and the xylene isomers (Figures 122 and 123) had influent concentration sequences consistently above the MDL but effluent concentration sequences at or below the MDL. Thus, no conclusions could be drawn with respect to the significance of the cross-correlation function. None of these compounds showed a significant diurnal pattern in their influent concentration sequence.

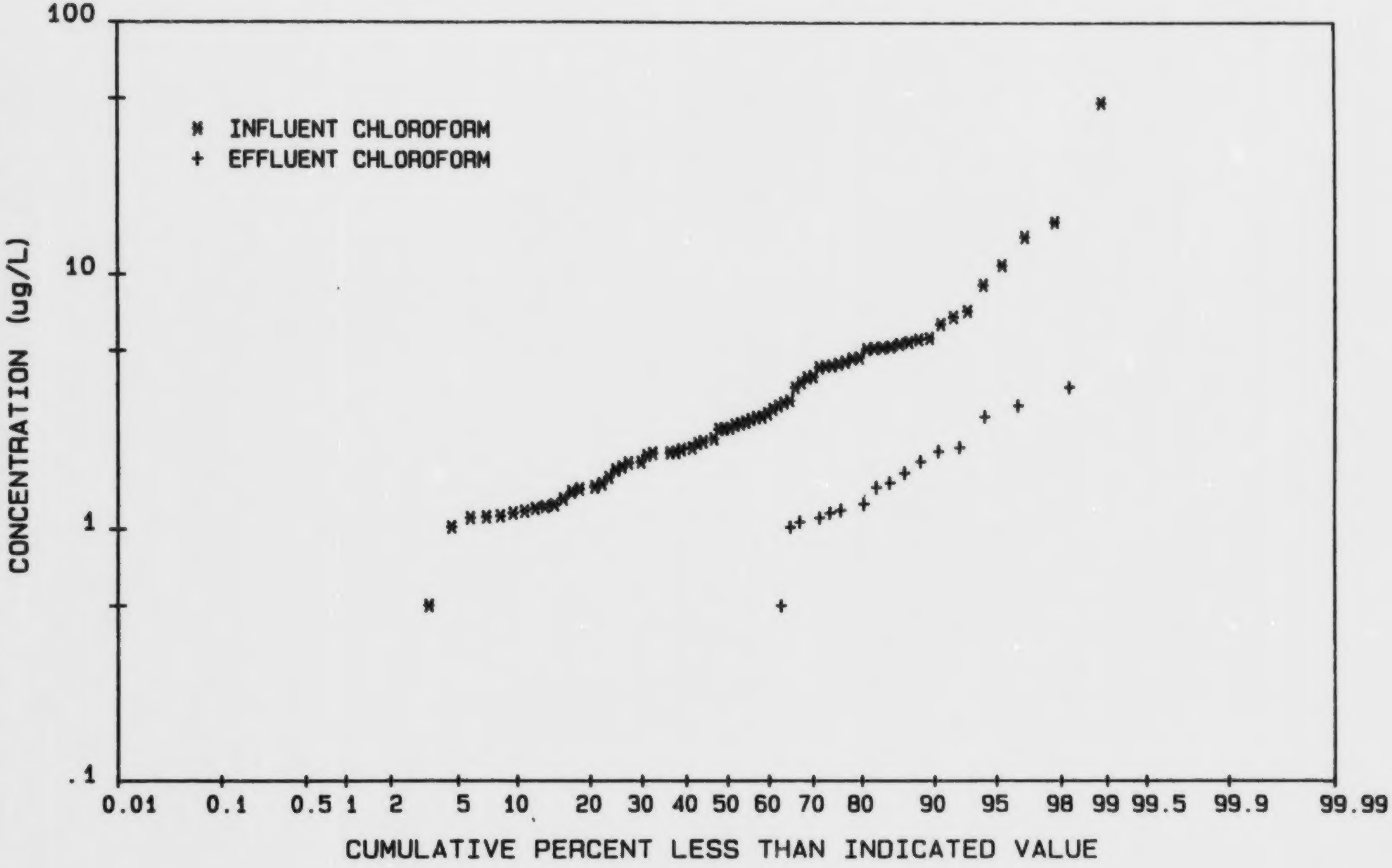

FIGURE 104 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT CHLOROFORM CONCENTRATION AT GALT STP

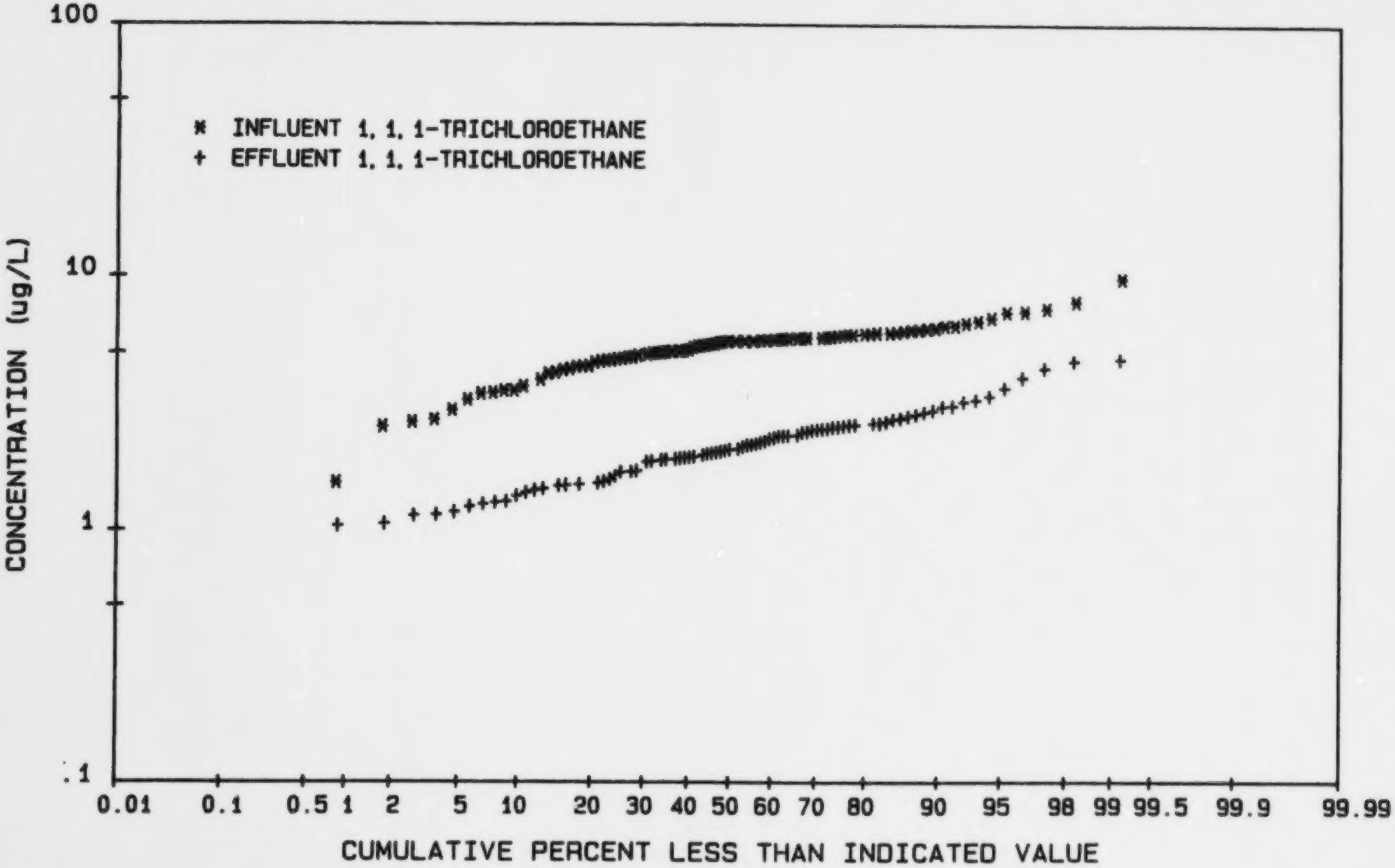

FIGURE 105 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT 1, 1, 1-TRICHLOROETHANE CONCENTRATION AT GALT STP

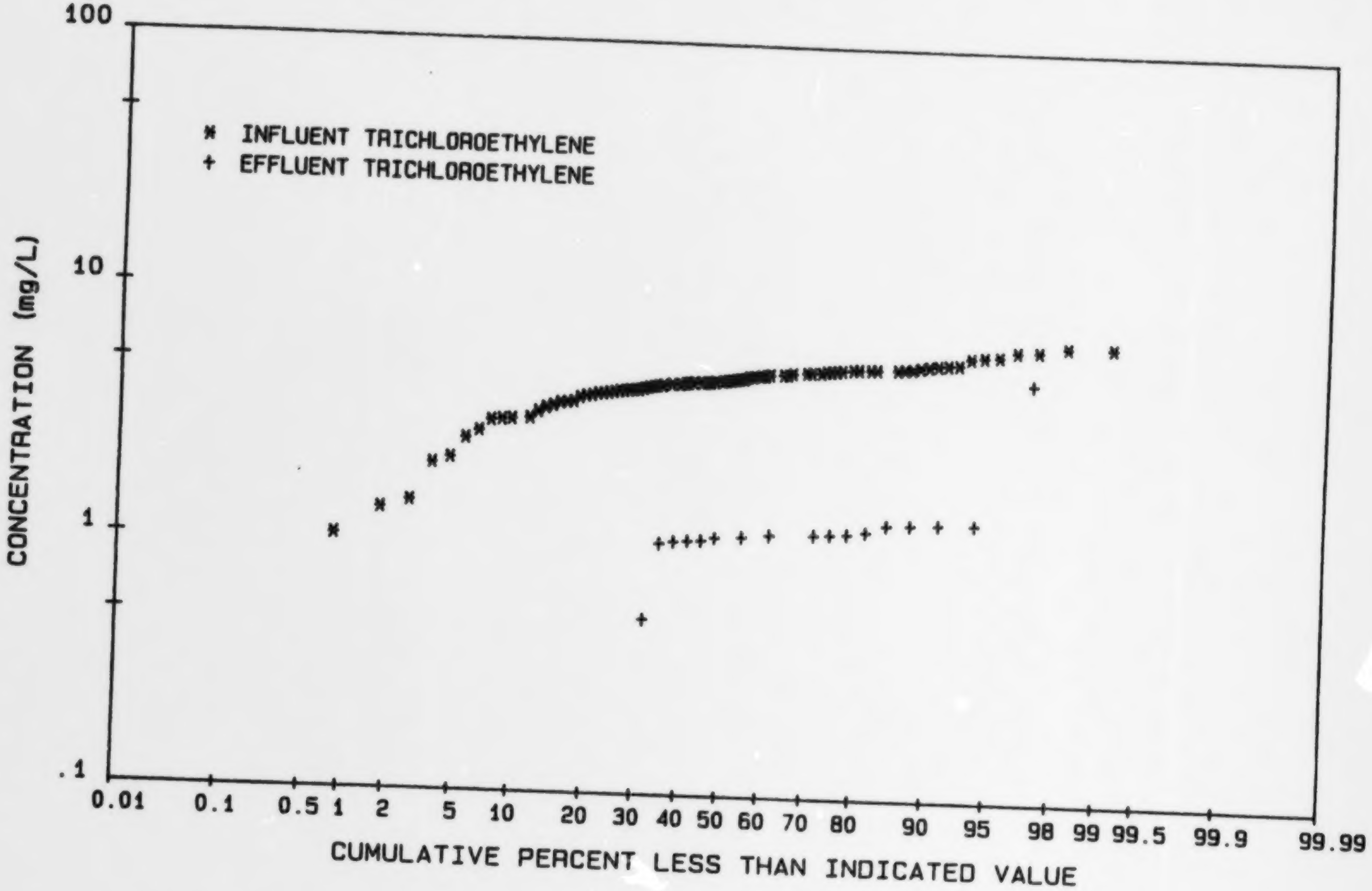

FIGURE 106 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE CONCENTRATION AT GALT STP

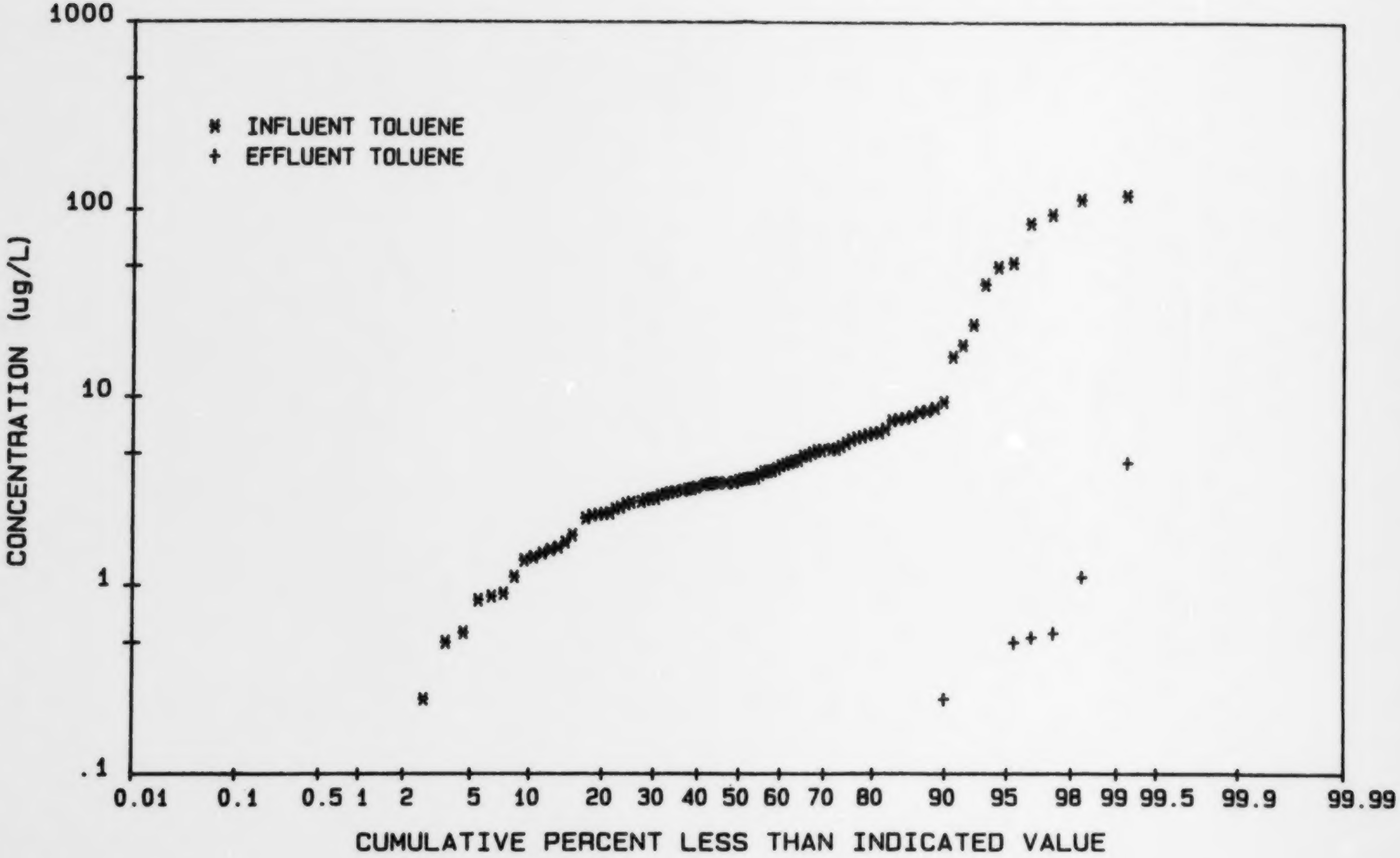

FIGURE 107 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TOLUENE CONCENTRATION AT GALT STP

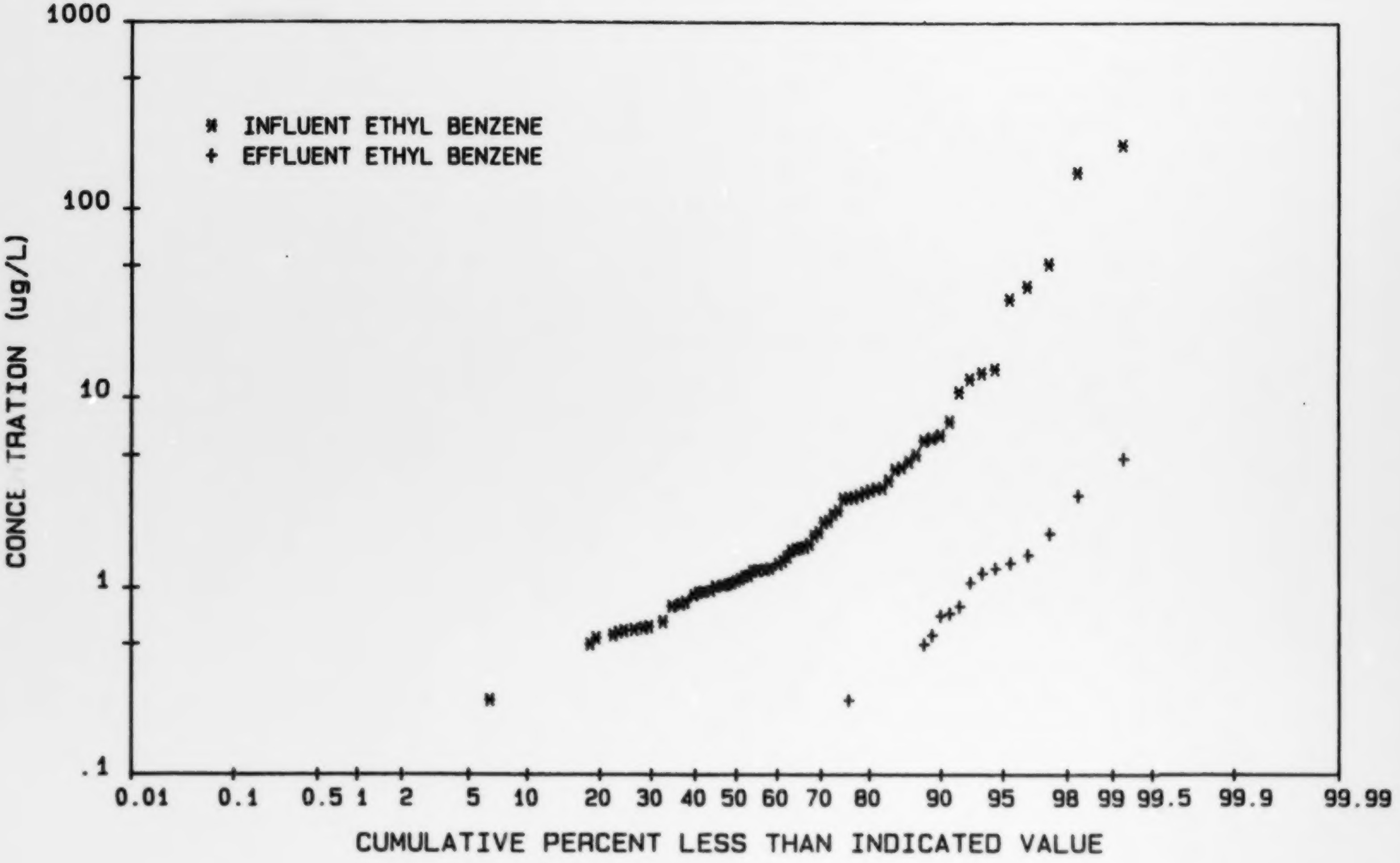

FIGURE 108 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT ETHYL BENZENE CONCENTRATION AT GALT STP

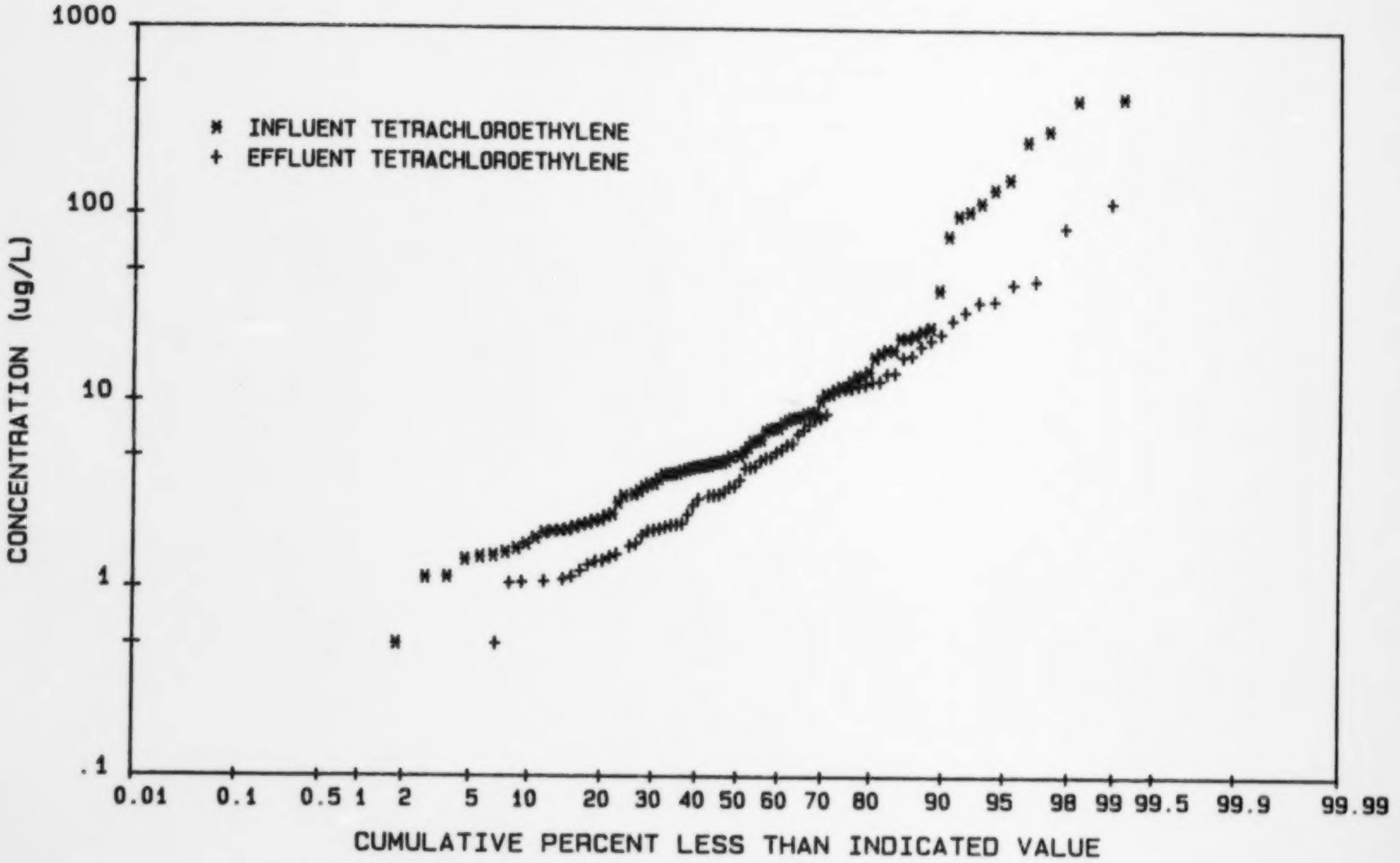

FIGURE 109 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT TETRACHLOROETHYLENE CONCENTRATION AT GALT STP

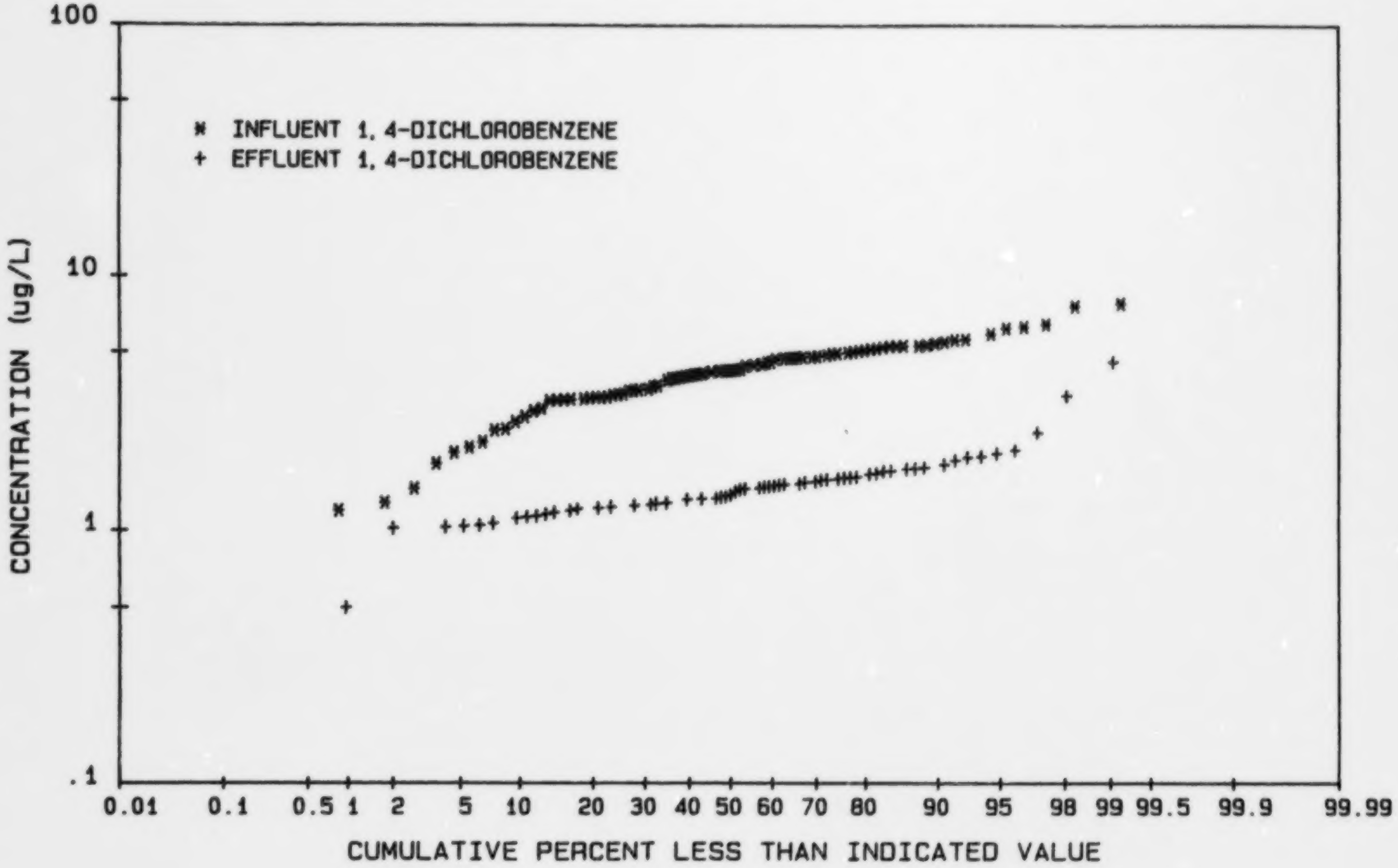

FIGURE 110 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT 1, 4-DICHLOROBENZENE CONCENTRATION AT GALT STP

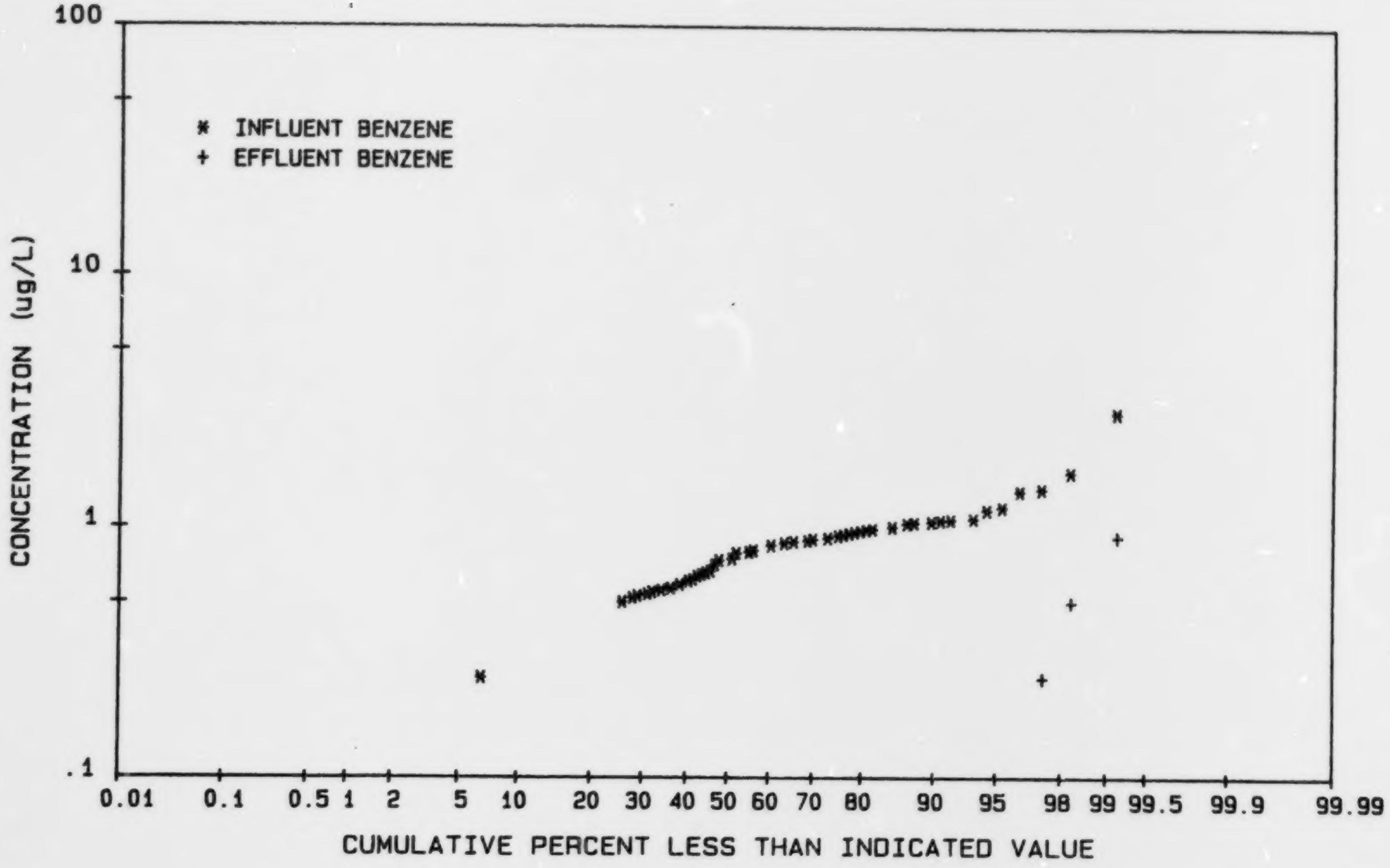

FIGURE 111 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT BENZENE CONCENTRATION AT GALT STP

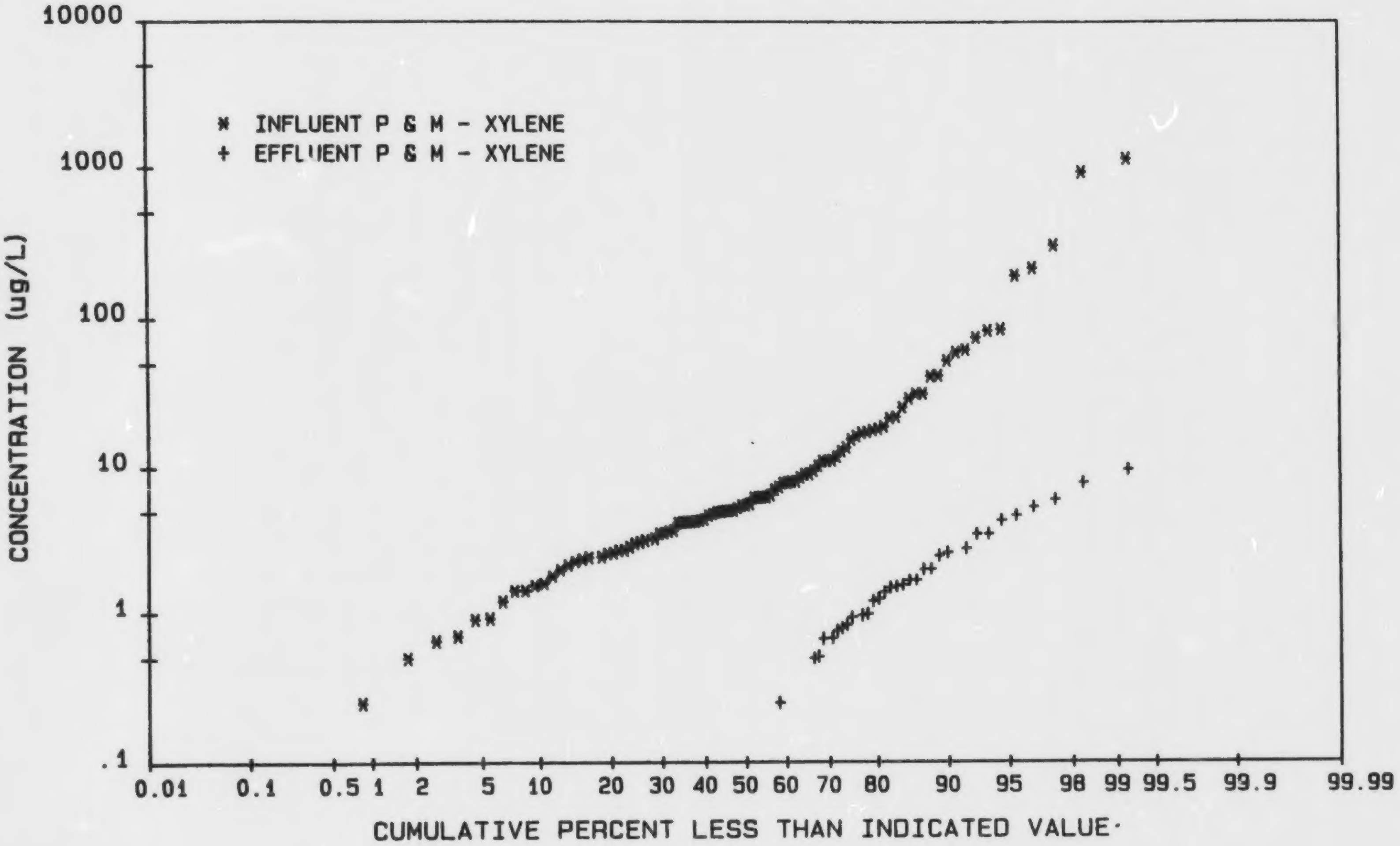

FIGURE 112 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT P & M - XYLENE CONCENTRATION AT GALT STP

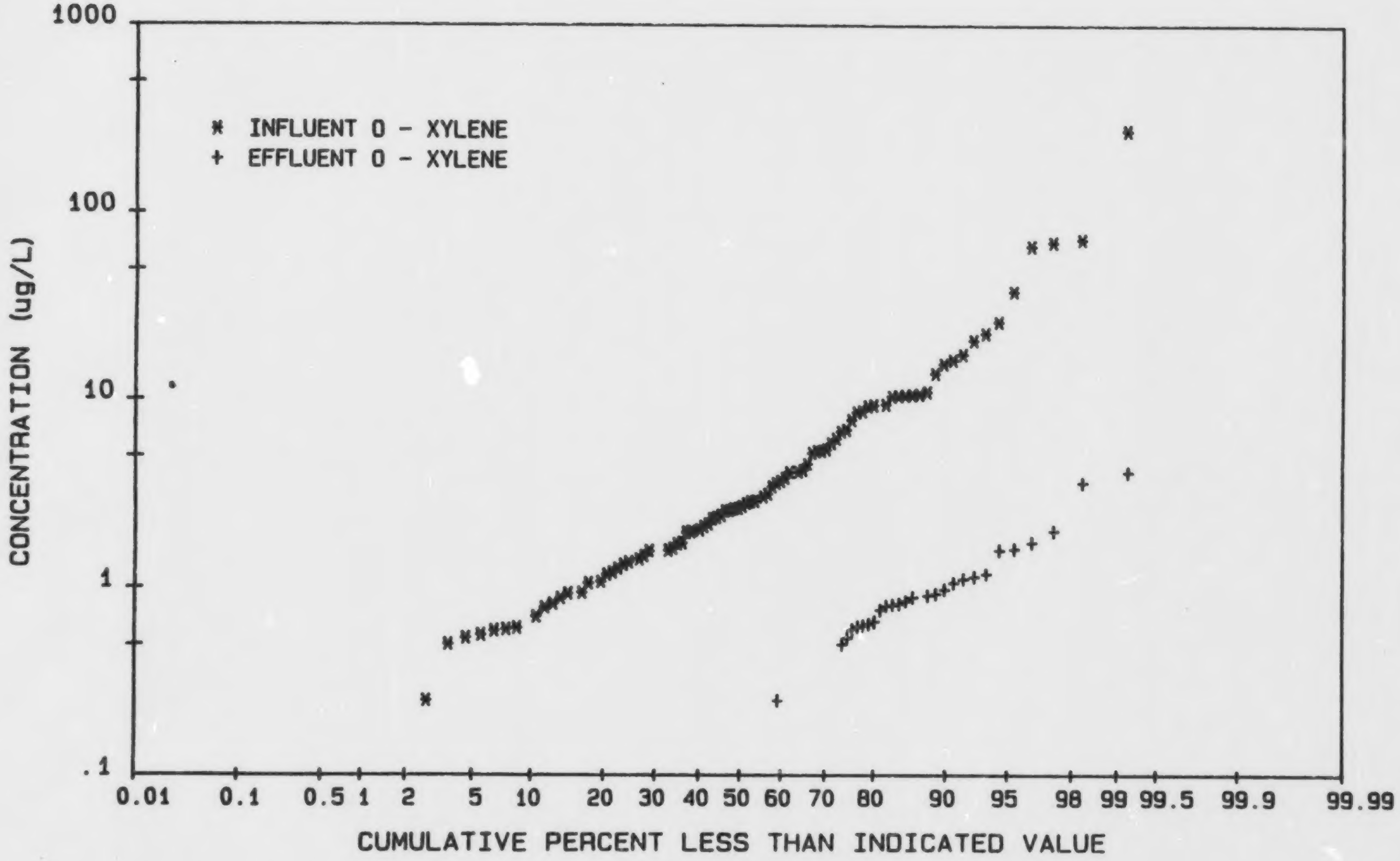

FIGURE 113 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT O - XYLENE CONCENTRATION AT GALT STP

Table 54
VOLATILE ORGANIC CONCENTRATION DATA FOR GALT STP

	Influent**					Effluent**				
Parameter*	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Chloroform	2.2	3.3	5.2	160.	9.5	0.9	1.0	0.5	50.0	1.9
1,1,1-trichloroethane	5.0	5.2	1.2	23.1	7.1	2.0	2.2	0.8	36.4	3.6
Trichloroethylene	4.2	4.4	1.1	25.0	6.2	1.0	1.0	0.4	40.0	1.4
Toluene	4.1	9.8	21.4	218.	53.8	0.3	0.3	0.4	133.	0.8
Ethylbenzene	1.5	7.0	27.3	390.	28.0	0.3	0.4	0.6	150.	1.3
Tetrachloroethylene	6.9	27.7	73.5	265.	146.0	3.3	8.6	16.7	194.	38.1
1,4-Dichlorobenzene	4.0	4.2	1.2	28.5	6.1	1.4	1.4	0.5	35.7	2.0
Benzene	0.7	0.8	0.4	50.0	1.2	0.3	0.3	0.07	23.3	0.3
p,m-Xylene	7.5	39.6	151.	381.	147.0	0.5	1.0	1.6	160.	4.4
o-Xylene	3.2	9.6	30.0	313.	38.3	0.4	0.5	0.6	120.	1.6

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*All concentrations reported in µg/L. RSD reported in %.

**Based on 99 samples.

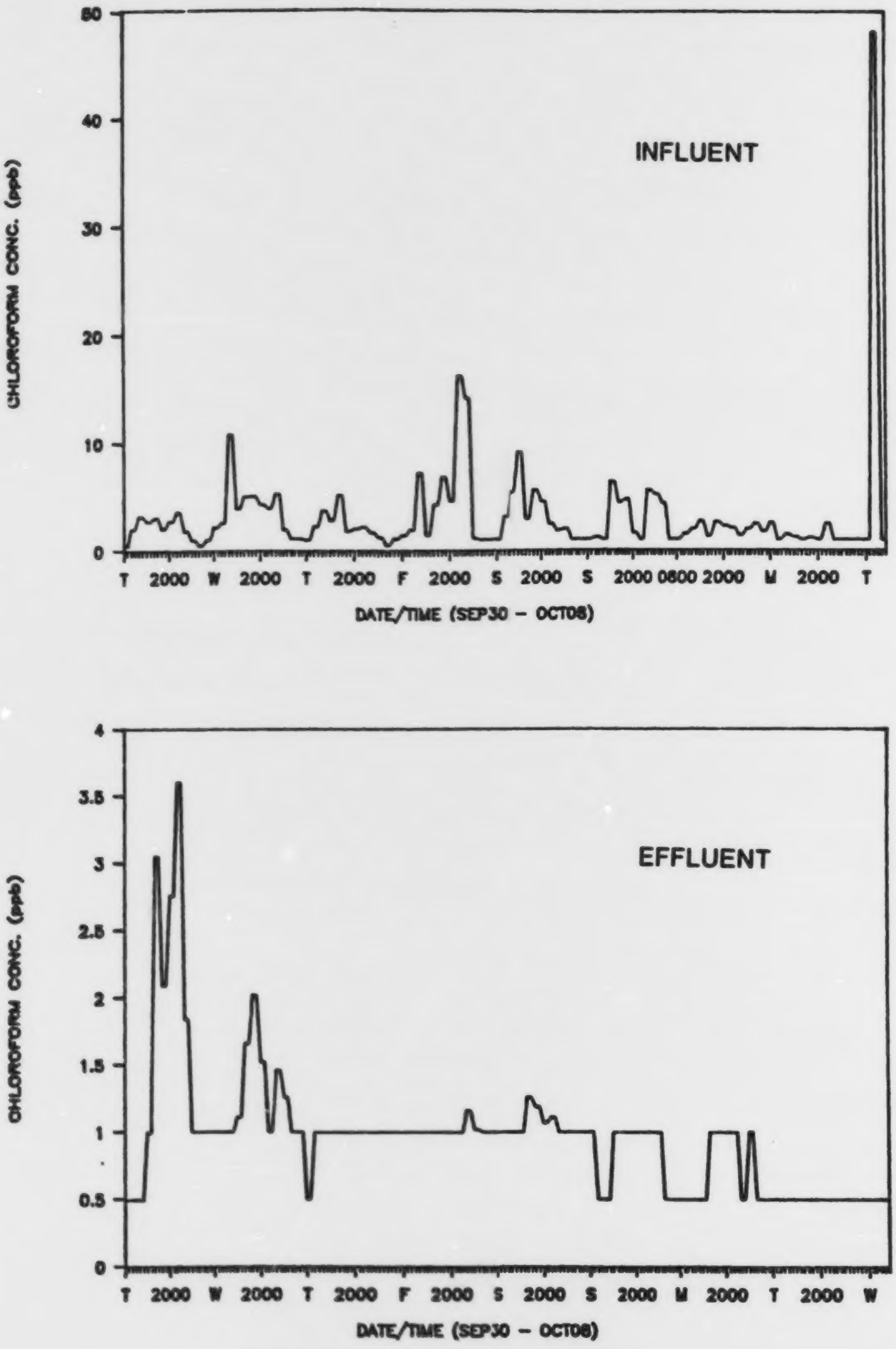
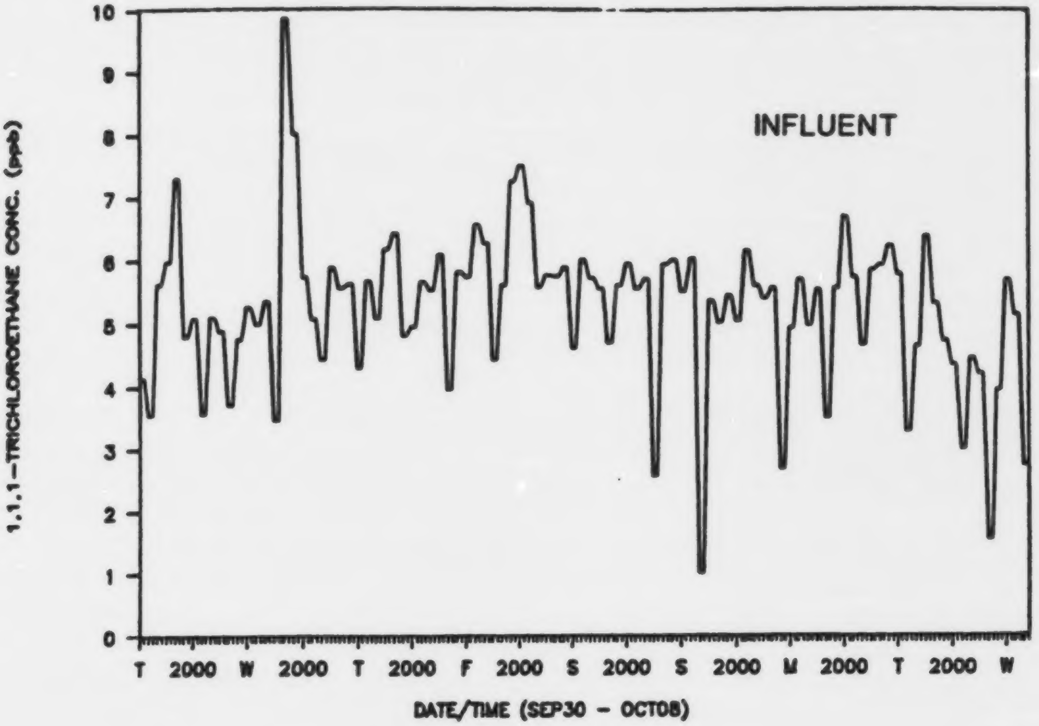


FIGURE 114: CHRONOLOGY OF INFLUENT AND EFFLUENT CHLOROFORM AT GALT WPCP



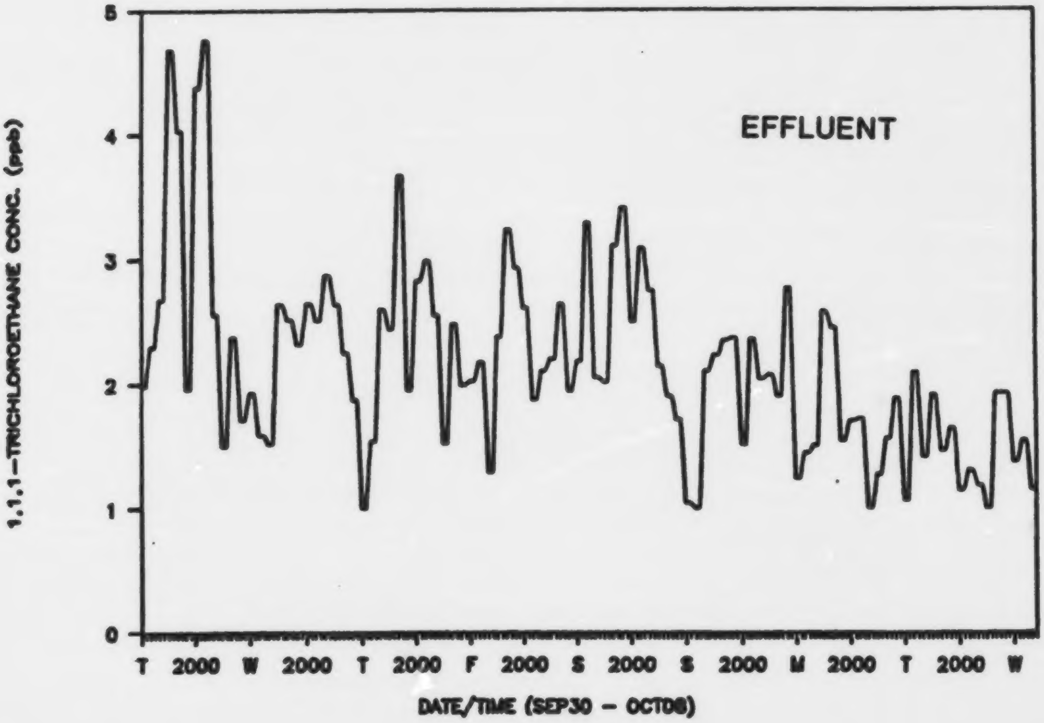


FIGURE 115: CHRONOLOGY OF INFLUENT AND EFFLUENT 1,1,1 - TRICHLOROETHANE AT GALT WPCP

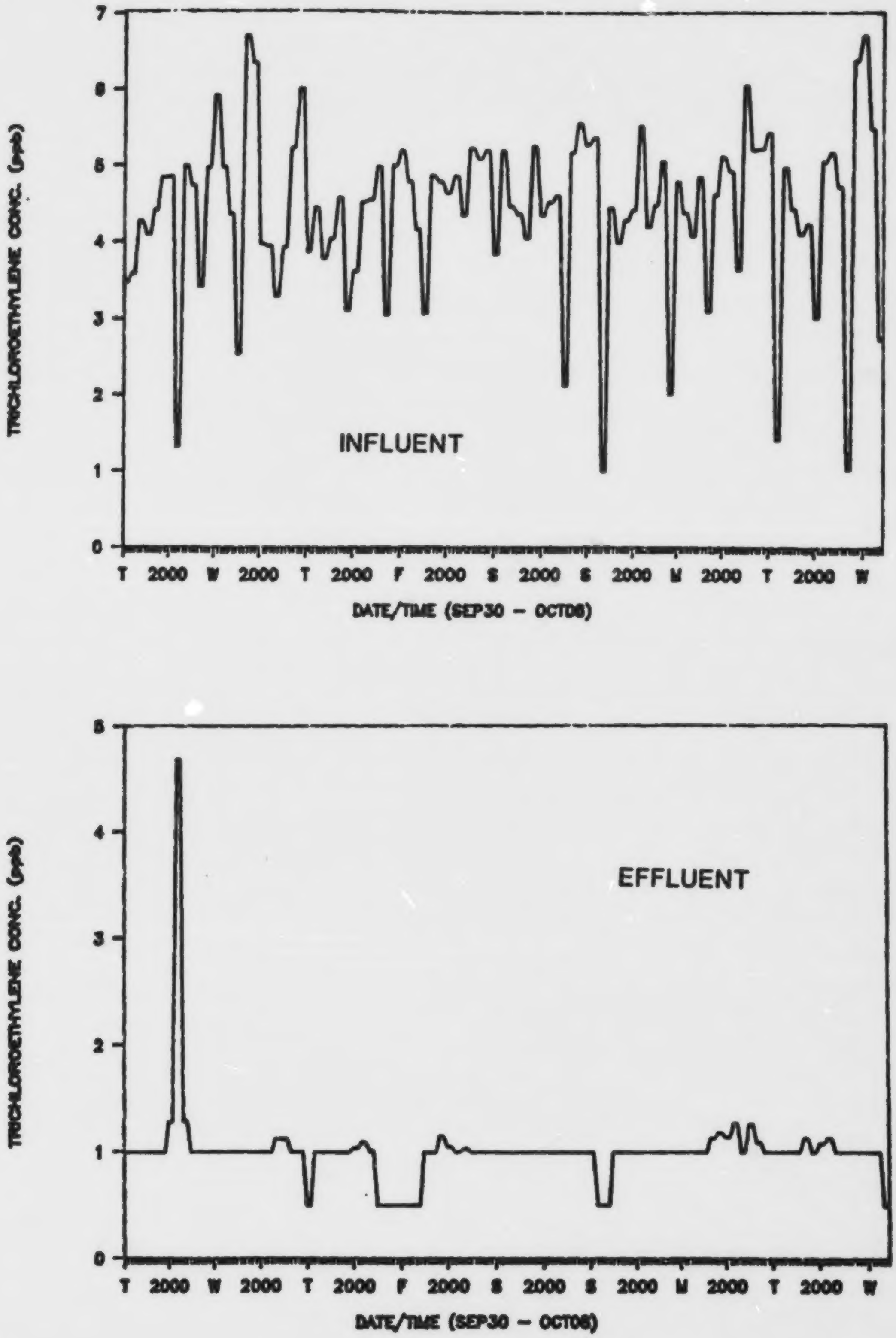


FIGURE 116: CHRONOLOGY OF INFLUENT AND EFFLUENT TRICHLOROETHYLENE AT GALT WPCP

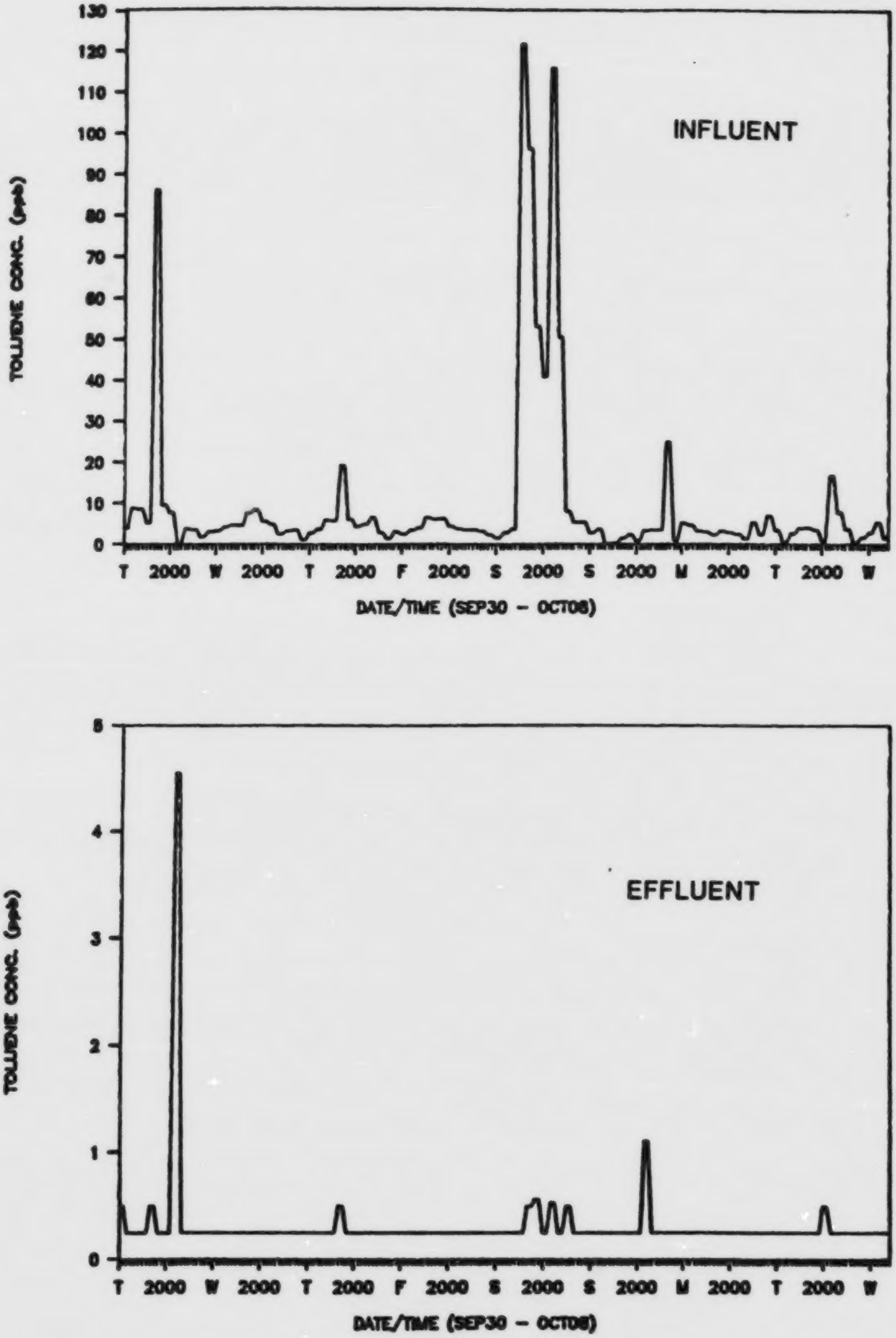


FIGURE 117: CHRONOLOGY OF INFLUENT AND EFFLUENT TOLUENE AT GALT WPCP

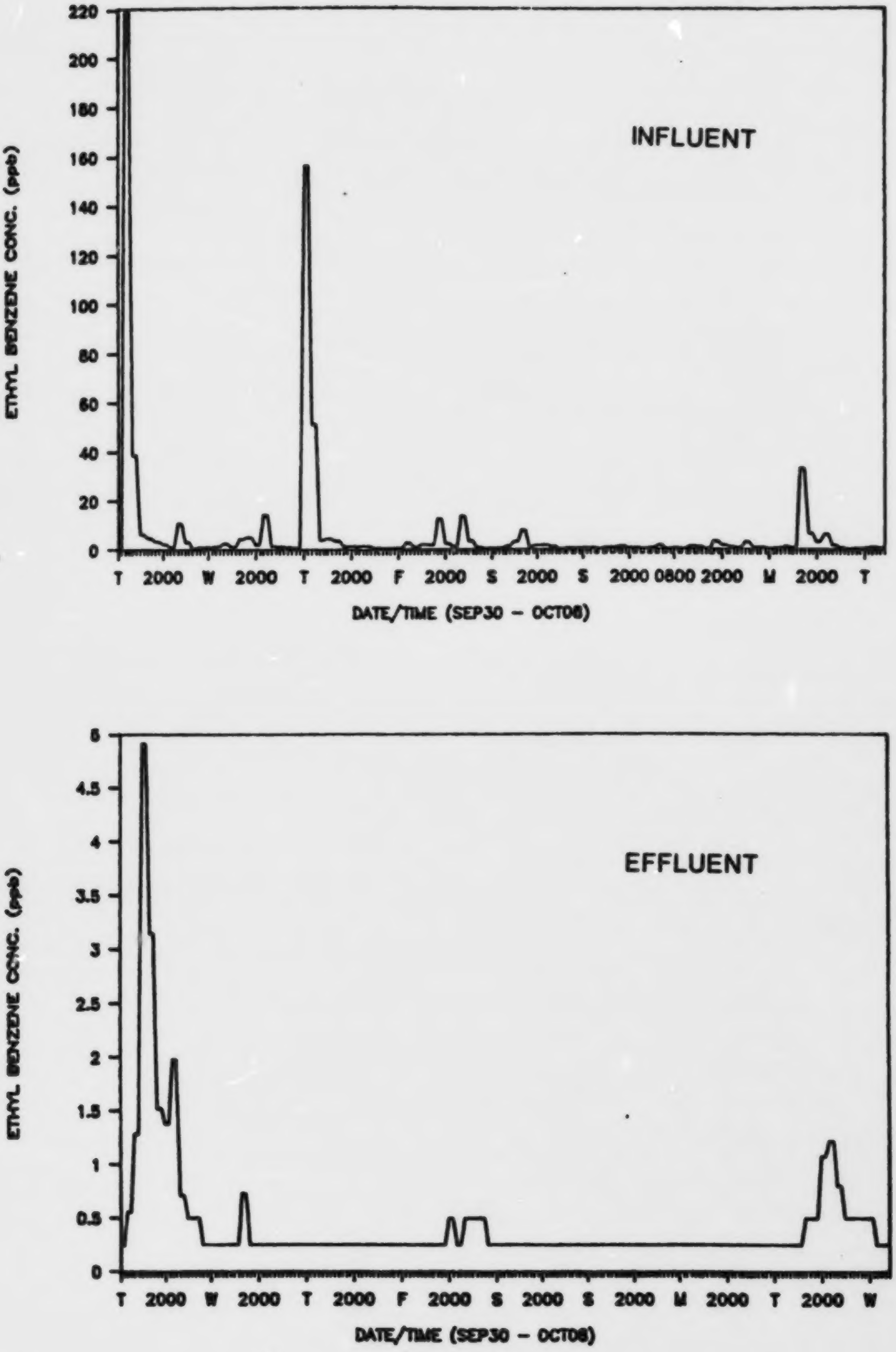
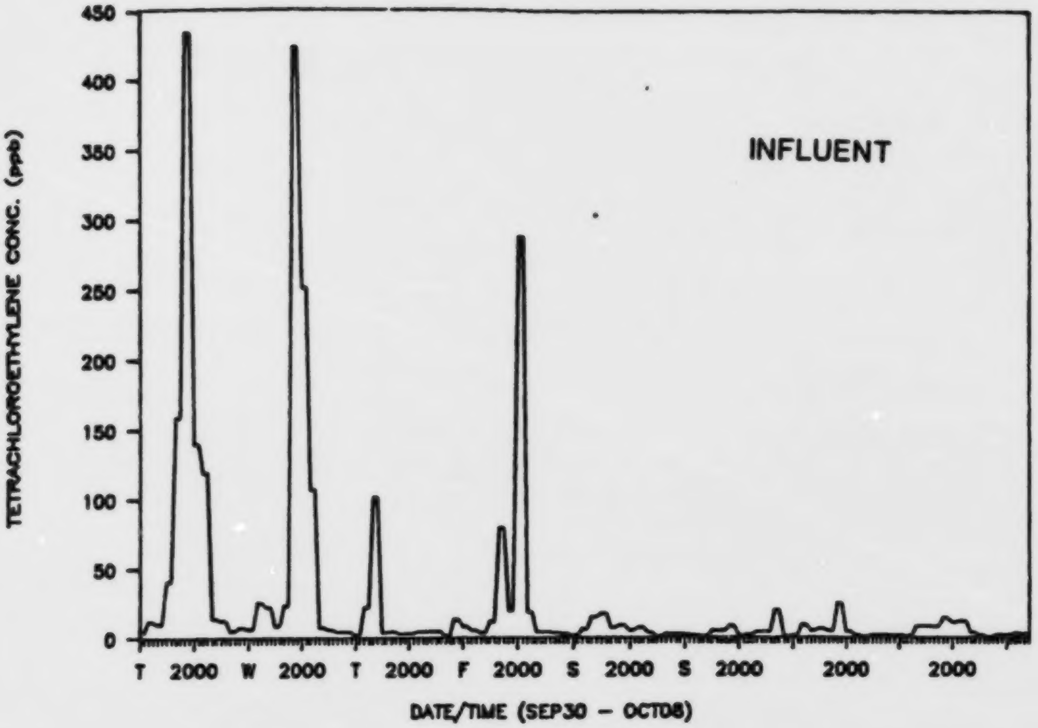


FIGURE 118: CHRONOLOGY OF INFLUENT AND EFFLUENT ETHYL BENZENE AT GALT WPCP



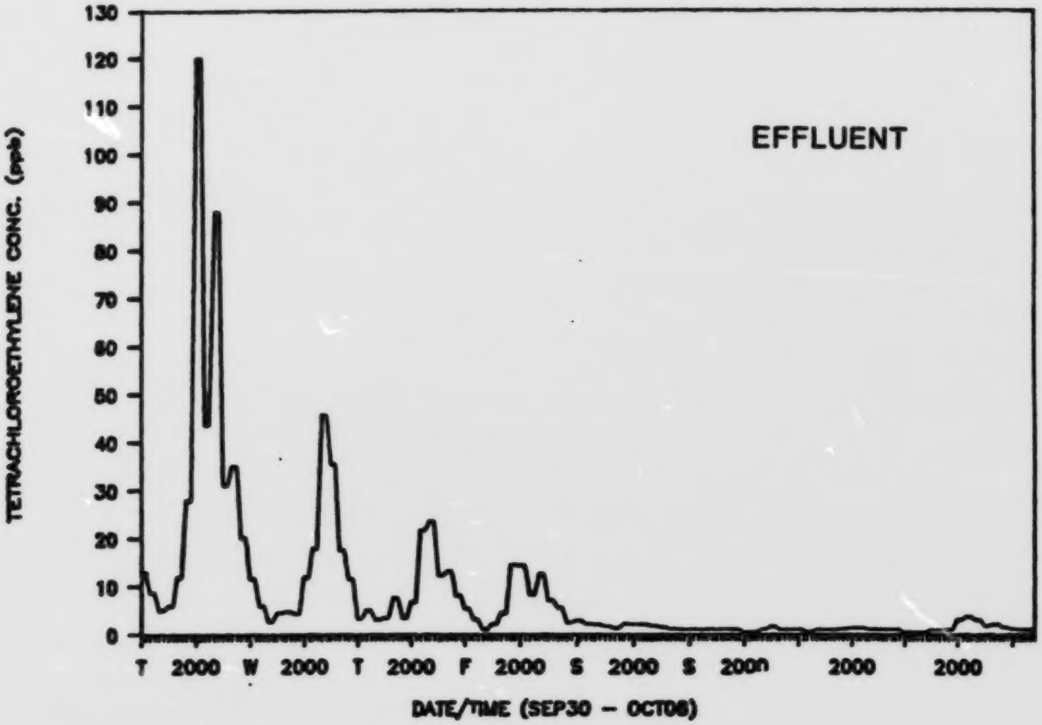


FIGURE 119: CHRONOLOGY OF INFLUENT AND EFFLUENT TETRACHLOROETHYLENE AT GALT WPCP

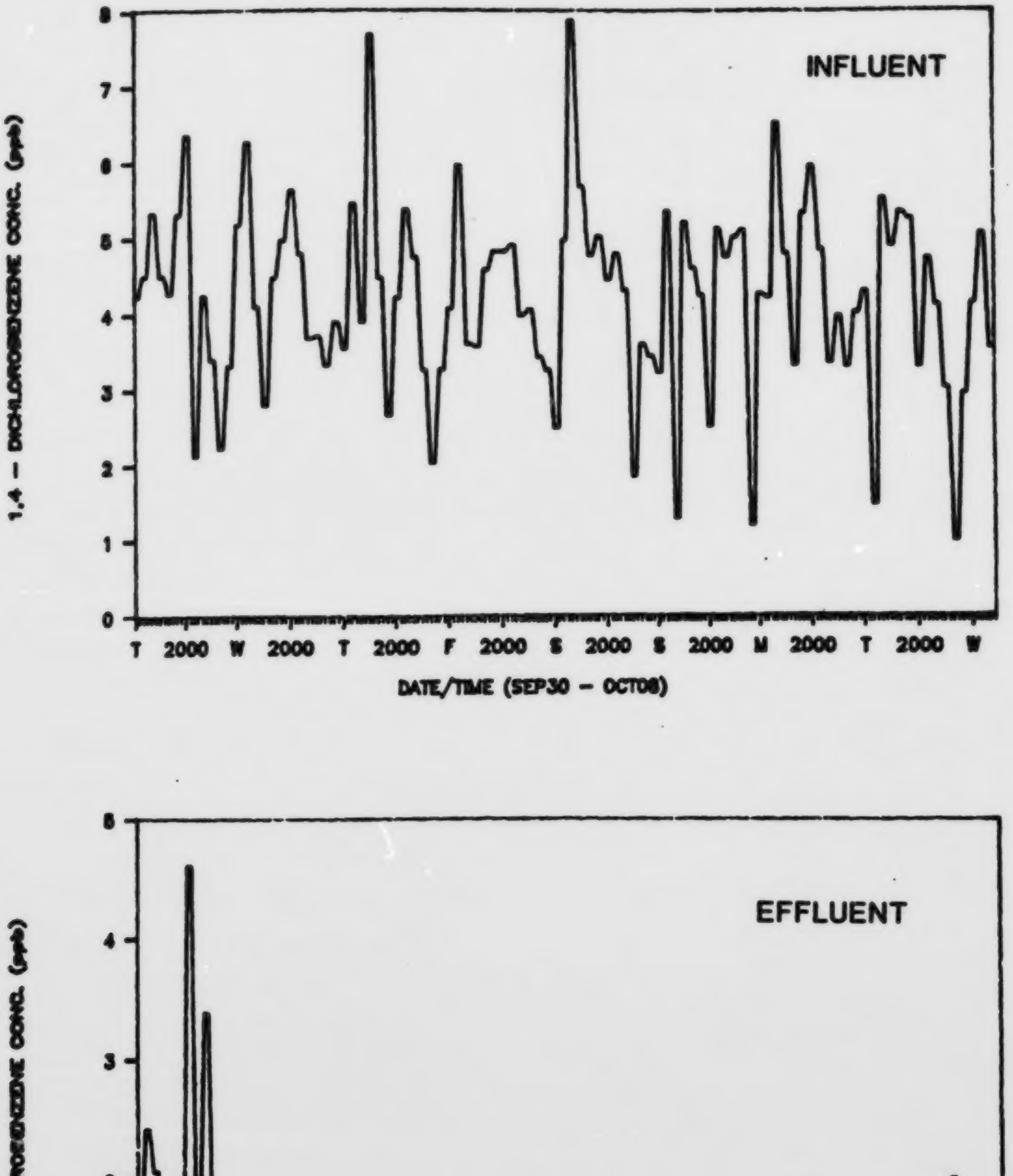


FIGURE 120: CHRONOLOGY OF INFLUENT AND EFFLUENT 1,4 – DICHLOROBENZENE AT GALT WPCP

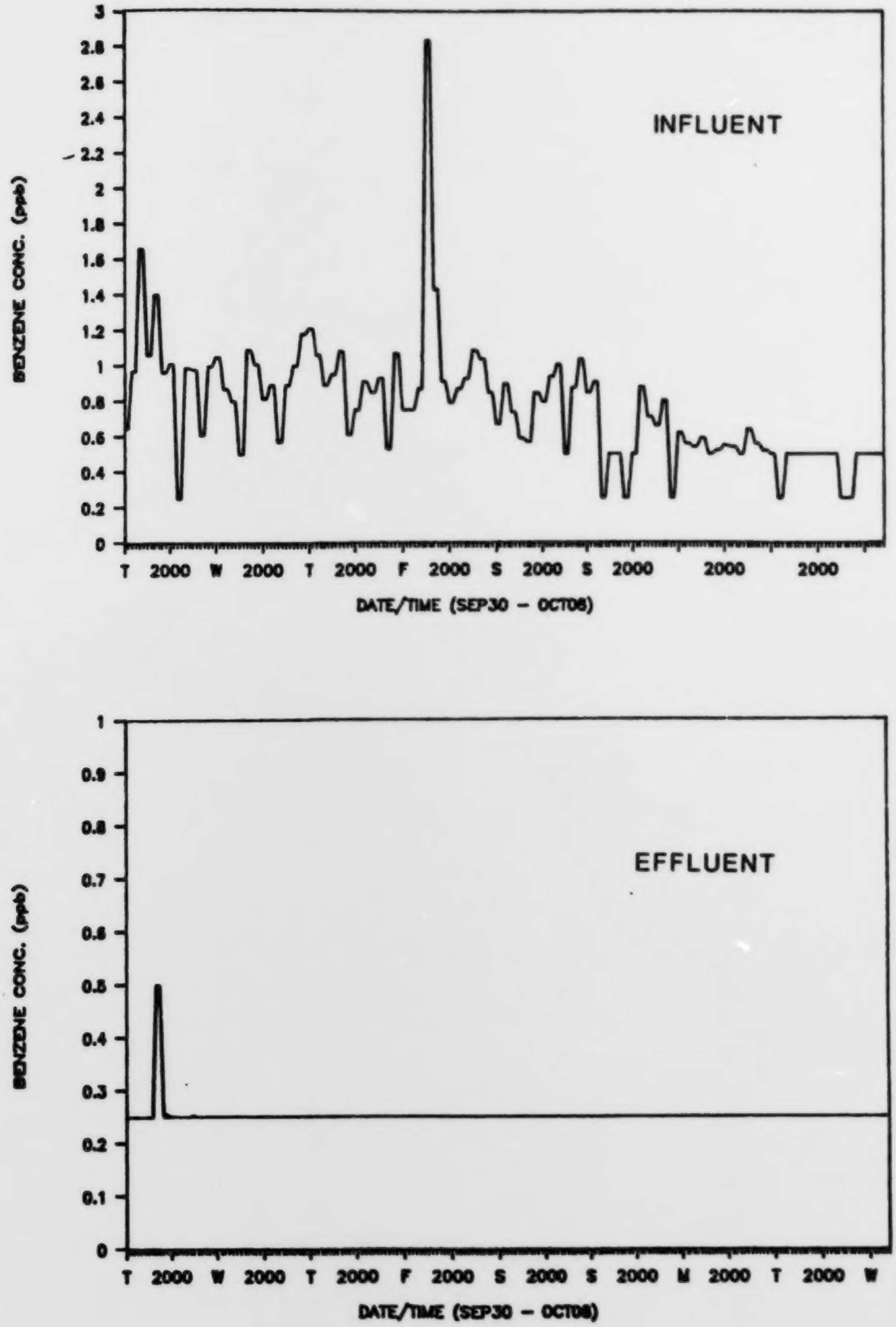


FIGURE 121: CHRONOLOGY OF INFLUENT AND EFFLUENT BENZENE AT GALT WPCP

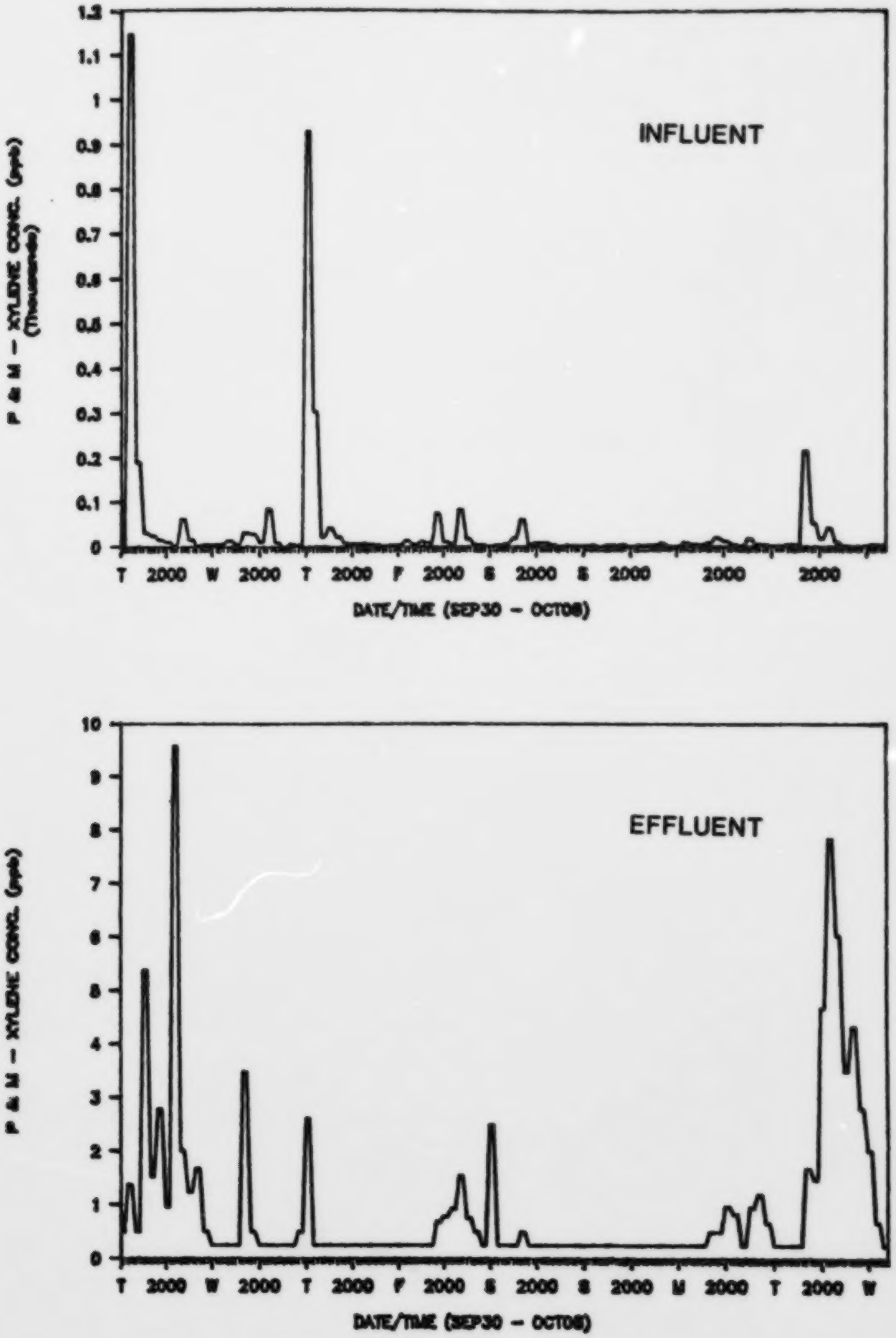
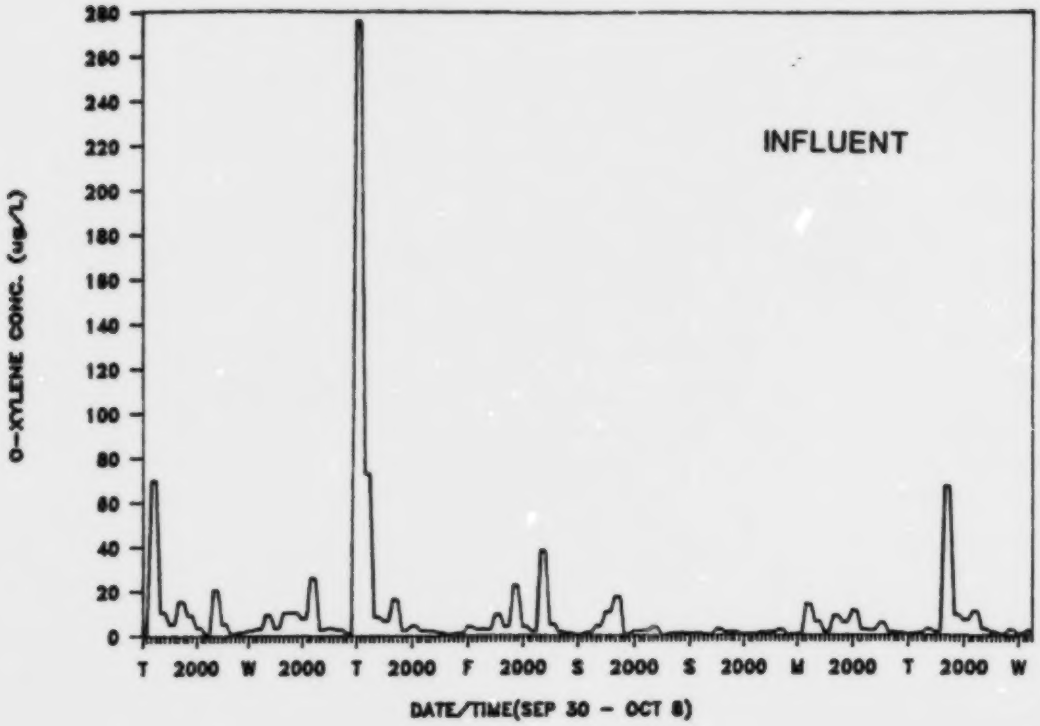


FIGURE 122: CHRONOLOGY OF INFLUENT AND EFFLUENT P&M XYLENE AT GALT WPCP



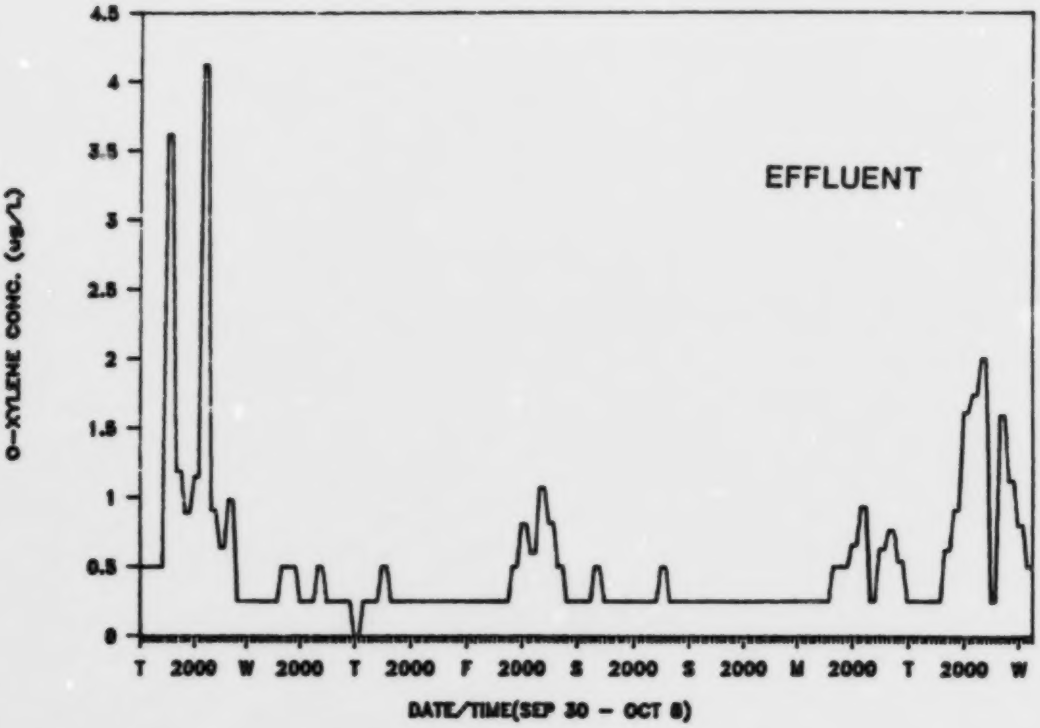


FIGURE 123: CHRONOLOGY OF INFLUENT AND EFFLUENT O - XYLENE AT GALT WPCP

The 1,1,1-trichloroethane influent and effluent concentration sequences (Figure 115) exhibited no diurnal pattern but the effluent concentration was significantly correlated to the influent concentration. The tetrachloroethylene influent concentration sequence (Figure 119) was dominated by four concentration peaks over the first four days of sampling with a strong diurnal pattern. These influent peaks produced significant increases in the effluent concentration. The 1,4-dichlorobenzene influent and effluent sequences were similar to those of 1,1,1-trichloroethane in that no discernible pattern could be identified but there appeared to be a significant effect of the influent concentration on the effluent. In both cases, the effluent concentrations were near the MDL.

Removal efficiencies for prevalent trace organic compounds are summarized in Table 55. Removal of aromatic hydrocarbons was virtually complete in all cases. The low reported removal for benzene (60 percent) relates to the substitution of half the MDL (0.25 µg/L) for 'not detected' in the calculation of the average concentration. Removal of chlorinated organics was generally consistent with that reported for Waterloo and Welland, averaging in the range from 60 to 80 percent.

Table 55
REMOVAL OF VOLATILE ORGANICS AT GALT STP

Compound	Removal (Percent) Based on Arithmetic Mean	Removal (Percent) Based on Geometric Mean
Chloroform	70	59
1,1,1-Trichloroethane	58	60
Trichloroethylene	77	76
Toluene	97	93
Ethylbenzene	94	80
Tetrachloroethylene	70	52
1,4-Dichlorobenzene	67	65
Benzene	63	57
p&m-Xylene	97	93
o-Xylene	95	88

5.2.3.3 PAHs

As identified in Section 2.3.3, only about thirty percent of influent and effluent samples at the Galt STP were analyzed for PAHs. Table 56 summarizes the frequency of detection of selected PAHs in these samples.

Table 56
FREQUENCY OF DETECTION OF PAHs AT GALT STP

	Frequency of Detection (%)					
	Influent			Effluent		
Compound	> MDL*	> Trace	Range (µg/L)	> MDL	> Trace	Range (µg/L)
Acenaphthene	0	0	ND	0	0	ND
Acenaphthylene	0	0	ND	0	0	ND
Anthracene	0	0	ND	0	0	ND
Phenanthrene	62	67	ND-8.9	54	80	ND-1.1
Benzo(a)anthracene	0	0	ND	0	0	ND
Chrysene	0	0	ND	0	0	ND
Benzo(b)fluoranthene	0	0	ND	0	3	ND-Trace
Benzo(k)fluoranthene	0	0	ND	0	0	ND
Benzo(ghi)perylene	0	0	ND	3	3	ND-1.0
Dibenzo(ah)anthracene	0	0	ND	0	0	ND
Fluoranthene	0	0	ND	0	0	ND
Fluorene	53	62	ND-87	94	94	ND-15.0
Indeno(1,2,3-cd)pyrene	0	0	ND	0	0	ND
Naphthalene	35	35	ND-100	0	0	ND
Pyrene	0	0	ND	0	3	ND-Trace
Benzo(a)pyrene	0	0	ND	0	3	ND-Trace

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*MDL varied from sample to sample depending on extraction volume and sample type but generally was in the range of 0.05 µg/L to 0.5 µg/L.

Only three PAHs - phenanthrene, fluorene and naphthalene - were identified in any influent samples. Of these three compounds, both phenanthrene and fluorene were present at concentrations exceeding the MDL in more than 50 percent of samples. Naphthalene was never identified, even at trace levels, in an effluent sample. Both phenanthrene and fluorene were quantified in more than 50 percent of effluent samples. Frequency distributions of influent and effluent concentrations of phenanthrene and fluorene are shown in Figures 124 and 125 respectively. Statistics characterizing

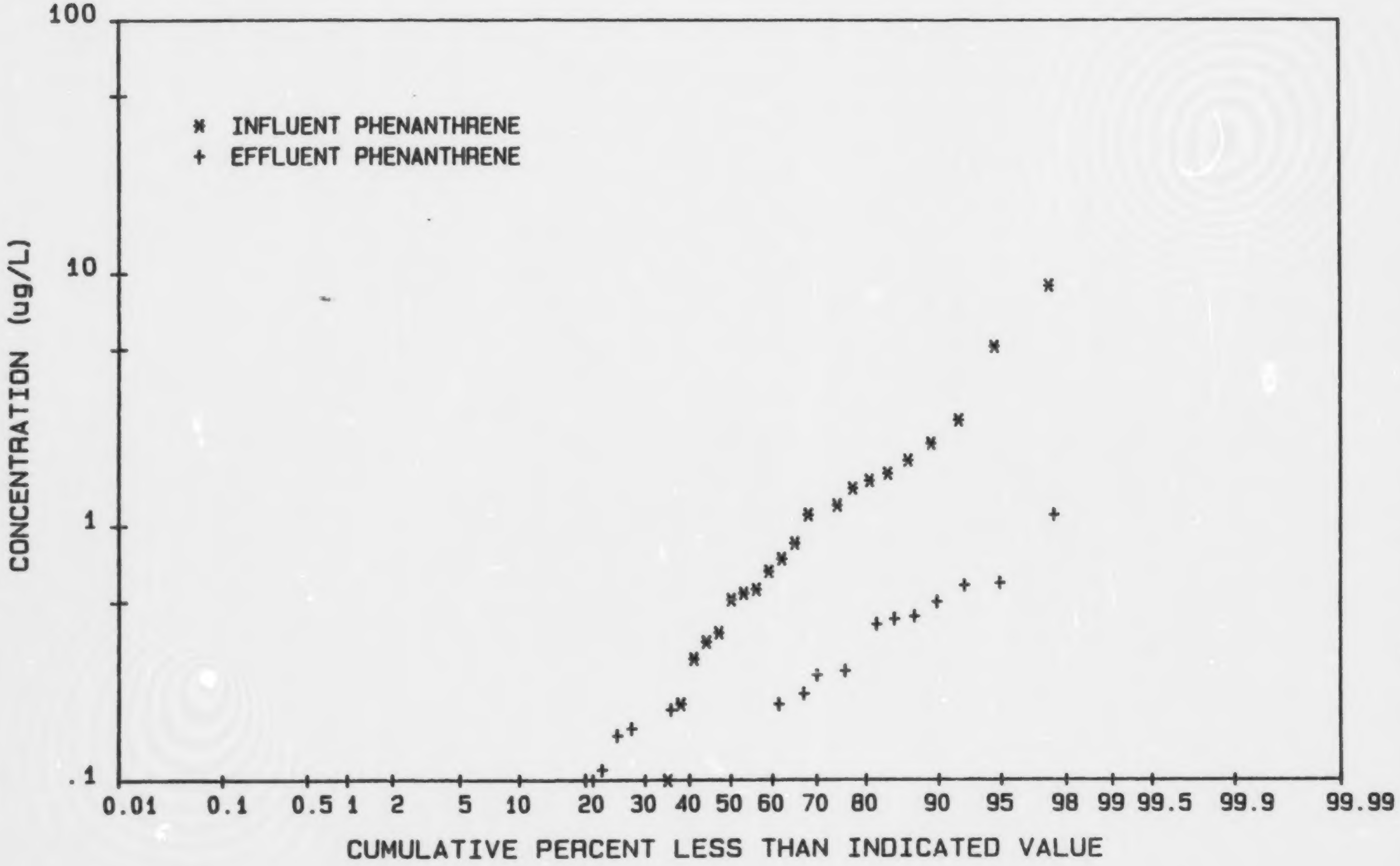

FIGURE 124 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT PHENANTHRENE CONCENTRATION AT GALT STP

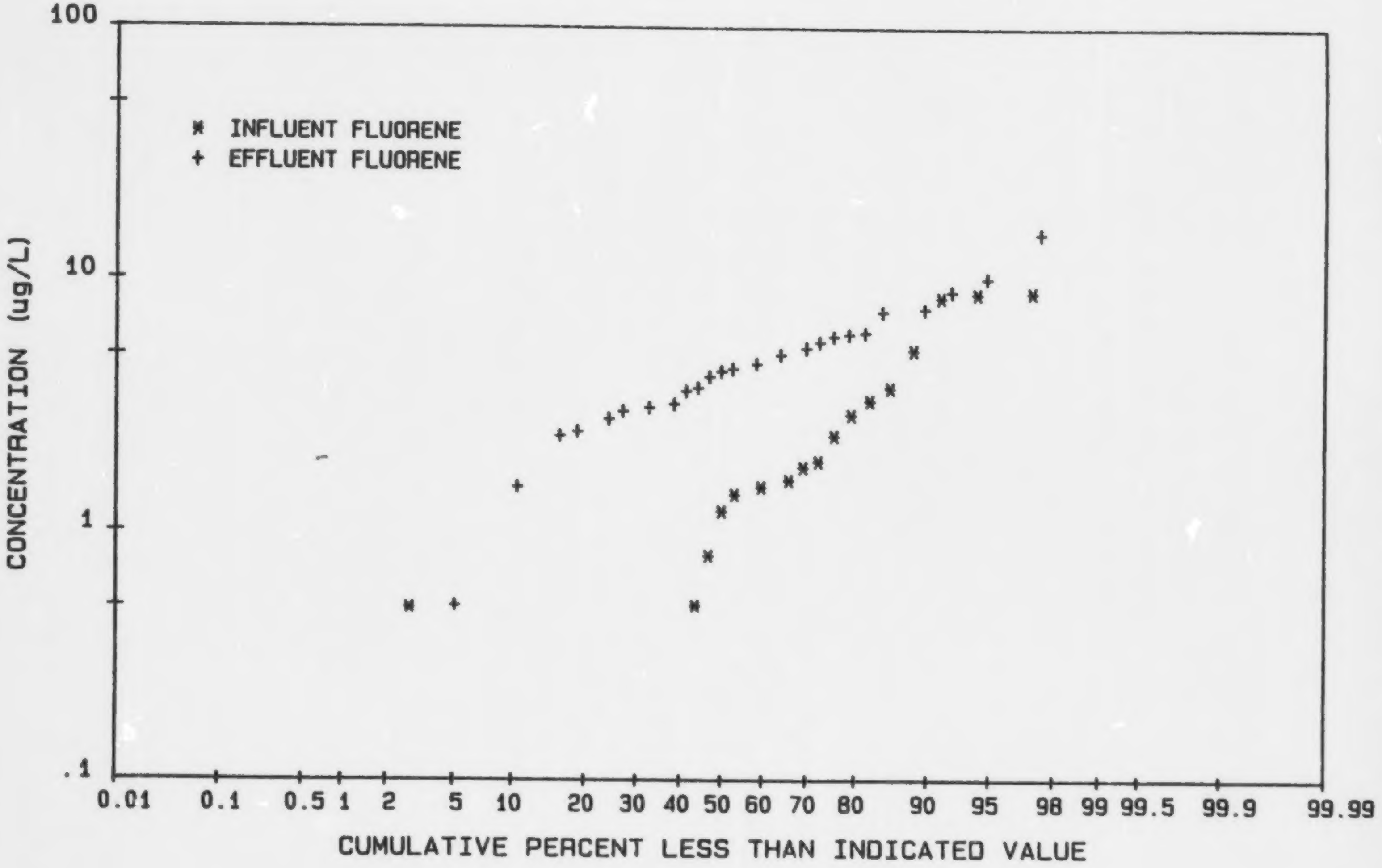

FIGURE 125 PROBABILITY DISTRIBUTION OF INFLUENT AND EFFLUENT FLUORENE CONCENTRATION AT GALT STP

these distributions are presented in Table 57. These data suggest a removal efficiency of approximately 55 percent for phenanthrene, based on geometric mean concentrations. The concentrations of fluorene were higher in the effluent samples than in the influent samples, despite similar analytical recoveries. The cause of this anomaly is unknown.

Recovery of the surrogate, terphenyl, from raw wastewaters at the Galt STP was slightly better than achieved at Waterloo or Welland, averaging 39.3 percent, but was also more variable (± 18.2 percent). Recoveries in secondary effluents were comparable to that achieved at Welland and Waterloo, averaging 35.5 percent, but also showed greater variability (± 16.2 percent).

5.3 Variability of Trace Contaminant Concentrations

The relative variability of the influent and effluent concentrations of selected conventional contaminants, metals and trace organics is summarized in Table 58, in terms of the relative standard deviation (RDS, percent) and the ratio of the 95th percentile concentration to the geometric mean.

As was the case at both Welland and Waterloo STPs, conventional parameters were generally more variable in the Galt STP influent than in the effluent, with the exception of filtered phosphorus. The effluent filtered phosphorus concentrations were affected by the plant's experimentation with ferrous chloride during the monitoring period.

Metal species generally were more variable in the influent at the Galt STP than at either of the other two plants monitored. Cadmium, chromium, copper, nickel, lead and zinc influent sequences all exhibited significant peaks over the monitoring period. In all cases except zinc, these influent peaks were removed to a high degree across the treatment plant and effluents showed less variability than influents in terms of the RSD and the ratio of 95th percentile value to geometric mean. Generally, metals appeared to be more variable in both influents and effluents than the conventional contaminants.

Table 57
PAH CONCENTRATION DATA FOR GALT STP

	Influent**					Effluent***				
Compound*	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile	Geo. Mean	Arith. Mean	Std.Dev.	RSD	95th Percentile
Phenanthrene	0.44	1.05	1.74	166.	6.24	0.20	0.26	0.20	76.9	0.69
Fluorene	1.20	1.99	2.40	121.	8.73	3.54	4.64	2.85	61.4	11.0

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*All concentrations reported in µg/L. RSD reported in %.

**Based on 33 samples.

***Based on 35 samples.

Table 58
VARIABILITY OF INFLUENT AND EFFLUENT AT GALT STP

Contaminant	Influent RSD (%)	Influent 95th %ile / Geo. Mean	Effluent RSD (%)	Effluent 95th %ile / Geo. Mean	Influent:Effluent Ratio RSD	Influent:Effluent Ratio 95th %ile / Geo. Mean
FOC	37.2	1.76	53.3	1.36	0.70	1.27
TSS	65.3	2.38	23.1	1.46	2.83	1.63
Total P	65.9	1.90	21.4	1.36	3.08	1.40
Filt. P	46.2	2.05	51.7	2.40	0.89	0.85
Cadmium	158.	7.83	50.0	2.27	3.16	3.45
Chromium	162.	5.03	26.1	1.49	6.21	3.38
Copper	69.9	2.61	27.6	1.63	2.53	1.60
Nickel	495.	16.7	102.	4.68	4.85	3.57
Lead	76.9	3.14	31.5	1.43	2.44	1.29
Zinc	64.8	2.23	48.7	2.41	1.33	0.93
Total Phenols	54.2	2.33	60.5	2.49	0.90	0.94
Chloroform	160.	4.32	50.0	2.11	3.20	2.05
Trichloroethylene	25.0	1.48	40.0	1.40	0.63	1.06
1,4-dichlorobenzene	28.5	1.53	35.7	1.43	0.80	1.07
Toluene	218.	13.1	133.	2.67	1.64	4.91
p, m-xylene	381.	19.6	160.	8.80	2.38	2.23
Tetrachloroethylene	265.	21.2	194.	11.5	1.36	1.84
1,1,1-trichloroethane	23.1	1.42	36.4	1.80	0.63	0.79
Ethylbenzene	390.	18.7	150.	4.33	2.60	4.32
Benzene	50.0	1.71	23.3	1.00	2.15	1.71
o-xylene	313.	12.0	120.	4.00	2.61	3.00

For trace organics identified frequently in influents and effluents at the Galt STP, some chlorinated compounds such as trichloroethylene, 1,4-dichlorobenzene and 1,1,1-trichloroethane exhibited minimal variability in the influents, being present in most samples at a consistent low concentration. Other chlorinated compounds, including chloroform and tetrachloroethylene, and aromatic hydrocarbons, such as xylene isomers, toluene and ethylbenzene, showed extreme influent variability. In virtually all cases, this variabiity was reduced significantly across the treatment plant although the variability of some organics including p&m-xylene and tetrachloroethylene was still relatively high.

Table 59 compares the variability of the conventional contaminants, metal species and selected organics as groups to each other and influent to effluent based on the normalized variance of each category of compounds.

Table 59
COMPARISON OF INFLUENT AND EFFLUENT VARIABILITY AT GALT STP

	Normalized Variance	
Contaminant Group	Influent	Effluent
Conventionals*	0.279	0.099
Metals**	5.21	0.296
Organics***	4.25	1.08

* Conventionals includes FOC, TSS, TP, Filt. P
** Metals includes Cd, Cr, Cu, Ni, Pb, Zn
*** Organics includes total phenols, chloroform, 1,1,1-trichloroethane, trichloroethylene p&m-xylene, o-xylene, 1,4-dichlorobenzene

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In all cases, effluents were significantly less variable in concentration than influents and both metals and organics showed a higher degree of variability than conventional contaminants. The Galt data, like the data for both Waterloo and Welland, also indicate that the metal species were less variable in the effluents than the organic compounds. However, at Galt, metals were more variable than organics in the influent.

In terms of the established criterion of variability (95th percentile concentration exceeds geometric mean by a factor of 2.0), filtered phosphorus was the only conventional contaminant which would be considered to exhibit significant variability in both influents and effluents. The effluent data, as noted, are influenced by the experimentation with ferrous chloride. All of the metal species exhibited significant variability in the Galt STP influent, but only cadmium, nickel and zinc exceeded the variability criterion in the effluent. Of the organic species summarized in Table 58, seven compounds (phenols, chloroform, p&m-xylene, o-xylene, ethylbenzene and tetrachloroethylene) exceeded the criterion in the influent stream. Five of these compounds (chloroform, toluene, p&m-xylene, o-xylene and ethylbenzene) exceeded the criterion in the effluent. Four of the five compounds which exhibited significant variability in the Galt STP effluent were aromatic hydrocarbons.

5.4 Toxicity of Influents and Effluents

The results of the 48-hour Daphnia and 96-hour rainbow trout acute toxicity and Ceriodaphnia chronic bioassays performed on the Galt STP effluents are shown in Table 60. Daphnia mortality generally occurred within the first 24-hours of the testing period, while Ceriodaphnia mortality occurred after three to four testing days.

5.4.1 Waste Loading and Treatment

Influent was acutely lethal (greater than 50 percent mortality) to Daphnia on two occasions during 'high load' and on no occasions during 'low load'; although low-level mortality (up to 40 percent) was observed in five samples from both loading conditions. Two influent samples were also lethal to rainbow trout during high waste loading but not low loading. Some effluent toxicity still occurred after secondary treatment, with the occurrence of low-level and acute lethality being more frequent during high waste load conditions. This suggests that loading in itself is not a good indicator of toxicity occurrence in the effluent, but suggests that high loading conditions may lead to elevated effluent toxicity.

Table 60

RESULTS OF ACUTE LETHALITY AND SUBLETHALITY TESTING PERFORMED ON THE GALT SEWAGE TREATMENT PLANT EFFLUENT SAMPLES

									LC50 (% v/v) (95% Confidence Limits)				Ceriodaphnia Tests	
	Plant Influent				Chlorinated Effluent								Survival	Reproductive Inhibition
Date/Time	pH	Total NH_3-N (mg/L)	Un-ionized NH_3 (mg/L)	TRC (mg/L)	pH	Total NH_3-N (mg/L)	Un-ionized NH_3 (mg/L)	TRC (mg/L)	Plant Influent Daphnia	Plant Influent Trout	Non-Chlorinated Secondary Effluent Daphnia	Chlorinated Secondary Effluent Daphnia	7-day LC50 (% v/v) (95% Confidence Limits) Chlorinated Effluent	Chronic Value (% v/v) (95% Confidence Limits) Chlorinated Effluent
High Loading														
30 Sep 86/10:00	7.96	28	0.96	L0.05	7.85	15	0.40	0.15	84** (67-100)		N.L.	N.L.	-	-
01 Oct 86/10:00	7.63	31	0.51	L0.05	8.03	15	0.60	0.30	N.L. (20)*	53 (41-68)	N.L.	N.L.	-	-
02 Oct 86/10:00	7.91	26	0.24	L0.05	8.08	15	0.67	0.35	N.L.		N.L.	N.L.	-	-
03 Oct 86/10:00	7.52	28	0.33	L0.05	7.88	15	0.40	0.35	N.L.		N.L.	N.L.	-	-
04 Oct 86/10:00	7.61	65	0.95	L0.05	7.91	20	0.57	0.18	N.L.		N.L.	N.L.	-	-
05 Oct 86/10:00	7.68	95	1.63	L0.05	7.92	23	0.66	0.38	16** (12-20)		N.L. (20)*	N.L. (10)*	88 (65-100)	71 (50-100)
06 Oct 86/10:00	7.83	55	1.32	0.10	7.88	23	0.62	0.35	N.L. (40)*	63 (49-79)	N.L. (20)*	N.L.	46 (33-63)	39 (30-50)
07 Oct 86/12:00	7.69	25	0.47	L0.05	8.01	28	1.08	0.10	N.L. (20)*		N.L. (10)*	N.L. (20)*	-	-
08 Oct 86/10:00	7.91	95	2.93	L0.05	7.97	19	0.67	0.15	N.L.		84 (55-100)	66 (44-99)	- -	- -
Low Loading														
01 Oct 86/4:00	7.80	12	0.28	L0.05	7.78	16	0.37	0.18	N.L.		N.L.	N.L.	-	-
02 Oct 86/4:00	7.62	12	0.19	L0.05	7.94	23	0.76	0.13	N.L.	N.L.	N.L.	N.L.	-	-
03 Oct 86/4:00	7.87	12	0.30	L0.05	7.88	20	0.54	0.15	N.L. (10)*		N.L.	N.L.	-	-
04 Oct 86/4:00	7.76	18	0.37	L0.05	7.88	22	0.59	0.18	N.L.		N.L.	N.L.	-	-
05 Oct 86/4:00	7.82	23	0.52	L0.05	7.92	20	0.57	0.38	N.L. (10)*		N.L.	N.L.	-	-
06 Oct 86/4:00	7.82	13	0.29	L0.05	8.01	23	0.83	0.50	N.L. (10)*		N.L. (10)*	100 (56-100)	- -	- -
07 Oct 86/4:00	7.70	11	0.21	0.07	7.95	19	0.64	0.15	N.L. (20)*	N.L.	N.L.	N.L.	N.L. (20)* -	71 (50-100)
08 Oct 86/4:00	7.72	14	0.28	0.07	7.98	27	0.92	0.10	N.L. (40)*		N.L.	N.L.	76 (37-100)	71 (50-100)

* Percent mortality observed in undiluted sample only reported in brackets.

** When NH_3 was removed, undiluted sample only produced 30% mortality (defined as non-lethal).

Total NH_3-N = total ammonia nitrogen.

NH_3 - un-ionized ammonia based on test pH and temperature calculated according to Emmerson *et al.* (1975).

L - less than

5.4.2 Chlorine

Chlorination of secondary effluent did not alter the toxicity to Daphnia in a consistent manner. Samples of non-chlorinated and chlorinated samples were both non-lethal on twelve occasions. Two chlorinated samples were more acutely toxic than comparable non-chlorinated samples. Total residual chlorine (TRC) is often dissipated during the aeration of toxicity tests, therefore the initial TRC measurement is not necessarily representative of the 48-hour exposure concentration. Consequently it is not surprising that chlorine toxicity is poorly expressed.

Chlorine is the most obvious potential toxicant in chlorinated effluent samples. Studies of chlorine toxicity(15,16,31) indicated that residual chlorine toxicity is species- and time-dependent. Arthur et al(15) clearly identified the greater sensitivity of fish (brook trout, coho salmon, fathead, sucker, walleye) to chlorinated sewage effluent than invertebrates (gammarus, stonefly, caddisfly, crayfish, snails). The 7-day LC50 values for fish ranged from 0.08 to 0.26 mg TRC/L, and for invertebrates from 0.2 to greater than 0.8 mg TRC/L. Larson et al(16) identified that trout (coho, salmon, brook trout, cutthroat trout), may live indefinitely at TRC concentrations near 0.05 mg/L. While some of the TRC values reported in this study exceeded these levels, no relationship exists between the concentrations measured and observed lethality. It is well recognized that sample aeration during tests causes chlorine concentrations to decline exponentially. In addition, the DPD method of TRC analysis does not provided accurate TRC measurements under approximately 0.05 mg/L. Therefore, the above discrepancies between chlorine toxicity and organism sensitivity may be accounted for by dynamic changes in TRC concentrations in the test vessel and poor detection limits for the DPD analytical method. No conclusions can be drawn concerning the importance of TRC from this study. Future tests employing continuous flow to ensure consistent TRC levels and more sensitive analytical measurement would clarify this issue.

5.4.3 Ammonia

Rainbow trout lethality was observed in only two of the four influent samples tested. Since the influent was not chlorinated, ammonia was one alternative measured toxicant. The documented rainbow trout 96-hour LC50 values for ammonia range from 0.1 to 2.0 mg un-ionized ammonia/L. The estimated 96-hour LC50 for un-ionized ammonia tested at pH 7.8 would be 0.5 mg/L. The two influent samples from Galt which caused lethality among rainbow trout contained un-ionized ammonia concentrations of 0.51 and 1.32 mg/L, indicating that ammonia was the likely cause of lethality. The samples which were non-lethal to rainbow trout contained levels of only 0.19 and 0.21 mg un-ionized ammonia/L.

Daphnia are less sensitive to ammonia than trout with LC50s generally in the range of 2 to 3 mg NH_3/L(14,34). The two influent samples which were lethal to Daphnia contained un-ionized ammonia of 0.96 and 1.63 mg NH_3/L. Un-ionized ammonia levels were sufficient to potentially contribute to the toxicity of lethal effluents. However, some non-lethal samples also contained equal or greater ammonia levels, indicating that other contaminants must have been present in the above lethal samples. Daphnia toxicity also decreased after lethal samples were treated with clinoptilolite resin to remove ammonia. Other toxic contaminants may have also been removed from that sample since two other samples with high un-ionized ammonia (06 October, 10:00, 1.32 mg/L and 08 October, 10:00, 2.93 mg/L) were not acutely lethal. Clinoptilolite treatment potentially exchanged other cation toxicants from the sample, such as Cu^{++} or Zn^{++} which can also be lethal to Daphnia(33).

5.4.4 Inorganics and Organics

The concentrations of some inorganic and organic contaminants were measured in influent and effluent samples (Tables 61 and 62, respectively). The samples which were lethal to Daphnia and rainbow trout are indicated. Table 28 presented the range of documented toxic concentrations for the same contaminants. It is clear that no one contaminant of those measured was present in all samples to consistently account for the observed lethality. For example, copper and zinc

Table 61
CONCENTRATIONS OF INORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (μg/L)

Sample Date	pH		Total NH_3-N		Cd		Cr		Cu		Ni		Pb		Zn	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
30.09.86[c]	8.58	7.32			1	1	53	19	100	21	27	28	10	5	146	46
01.10.86[d]	7.50	7.20			4	2	168	24	129	30	46	22	15	5	413	63
02.10.86	8.35	7.40			4	2	69	27	130	47	27	105	50	5	181	57
03.10.86	7.65	7.55			3	2	94	44	161	65	51	85	15	5	477	60
04.10.86	7.55	7.35			4	2	34	26	133	37	20	29	5	5	165	55
05.10.86[c]	7.70	7.50			1	1	22	23	111	34	16	20	10	5	145	43
06.10.86[d]	7.90	7.50			7	2	70	28	171	52	60	19	25	5	376	75
07.10.86	7.75	7.60		14.4	2	2	63	30	115	45	117	27	5	5	271	86
08.10.86[a,b]					6	4	88	32	129	66	30	73	20	5	203	68
Low Loading																
01.10.86	7.60	7.20		14.6	2	2	23	19	49	48	18	29	5	5	81	51
02.10.86	7.50	7.50	5.8	11.3	3	1	35	25	55	37	29	162	10	5	92	60
03.10.86	8.30	7.60		11.3	3	3	33	39	66	69	19	123	5	5	78	95
04.10.86	7.80	7.60		10.9	2	2	25	32	63	44	16	36	5	5	71	80
05.10.86	7.55	7.60		12.6	2	2	22	26	46	32	17	25	5	5	83	75
06.10.86[b]	7.40	7.50		15.0	2	2	34	27	48	38	24	28	10	10	72	84
07.10.86	7.50	7.70		12.9	2	11	82		149	32	41	27	15	5	223	189
08.10.86	7.50	7.52		12.2	20	5	252	35	112	80	41	100	5	5	119	132

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[a] Non-chlorinated and [b] chlorinated effluent sample toxic to Daphnia magna.

[c] Influent sample lethal to Daphnia magna

[d] Influent sample lethal to Salmo gairdneri

Table 62
CONCENTRATIONS OF ORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (µg/L)

Sample Date	Phenolics (4-AAP)	Chloroform In	Chloroform Out	1,1,1-Trichloroethane In	1,1,1-Trichloroethane Out	Benzene In	Benzene Out	Trichloro-ethylene In	Trichloro-ethylene Out	Toluene In	Toluene Out	Tetrachloro-ethylene In	Tetrachloro-ethylene Out	Ethyl Benzene In	Ethyl Benzene Out	p & m-Xylene In	p & m-Xylene Out	1,4-Dichloro-benzene In	1,4-Dichloro-benzene Out
High Flow																			
30.09.86[c]	1.0	2.01	0.50	3.56	2.30	0.97	0.25	3.59	1.00	0.25	0.25	12.23	8.75	218.98	0.36	1,146.77	1.38	4.51	2.43
01.10.86[d]	5.0	2.60	1.00	4.99	1.39	0.87	0.25	4.98	1.00	4.21	0.25	25.62	6.02	1.36	0.25	6.51	0.25	6.28	1.16
02.10.86	7.8	2.27	1.00	5.67	1.54	1.06	0.25	4.44	1.00	3.76	0.25	22.37	5.07	50.86	0.25	302.63	0.25	5.46	1.14
03.10.86	3.4	1.95	1.00	6.58	2.17	0.75	0.25	4.79	0.50	3.35	0.25	5.39	3.17	2.62	0.25	12.84	0.25	5.96	1.07
04.10.86	2.4	3.14	1.00	6.01	3.29	0.90	0.25	5.20	1.00	2.79	0.25	6.16	2.18	0.66	0.25	3.04	0.25	4.96	1.00
05.10.86[c]	3.2	1.21	0.50	6.03	1.00	0.91	0.25	5.37	0.50	3.56	0.25	1.14	1.00	0.58	0.25	2.75	0.25	5.35	1.00
06.10.86[d]	5.2	1.51	0.50	5.70	1.44	0.56	0.25	4.39	1.00	4.62	0.25	8.98	0.50	0.25	0.25	8.98	0.25	4.22	1.05
07.10.86	4.6	1.47	0.50	4.64	1.41	0.50	0.25	4.99	1.00	2.60	0.25	8.26	0.50	1.17	0.25	5.57	0.25	5.53	1.35
08.10.86[a,b]	8.0	48.14	0.50	5.13	1.54	0.50	0.25	5.49	1.00	5.33	0.25	3.17	1.00	0.97	0.25	4.98	0.68	5.05	1.18
Low Flow																			
01.10.86	2.8	0.50	1.00	3.70	2.38	0.61	0.253	3.42	1.00	1.84	0.25	5.15	35.03	0.39	0.50	3.19	1.68	2.23	1.77
02.10.86	1.0	1.16	1,00	5.56	2.25	1.00	0.253	5.23	1.00	3.48	0.25	4.33	17.63	0.82	0.25	5.11	0.25	3.33	1.36
03.10.86	6.8	0.50	1.00	3.93	2.48	0.53	0.253	3.04	0.50	1.48	0.25	1.62	13.13	0.50	0.25	1.81	0.25	2.03	1.27
04.10.86	6.8	1.02	1.00	5.74	2.64	1.04	0.25	5.09	1.00	3.16	0.25	3.30	5.56	0.92	0.50	4.84	0.50	3.42	1.20
05.10.86	2.4	1.00	1.00	5.94	1.90	0.88	0.25	5.18	1.00	5.32	0.25	2.42	1.08	09.50	0.25	2.38	0.25	3.60	1.33
06.10.86[b]	3.0	4.38	0.50	5.56	1.90	0.80	0.25	5.07	1.00	24.87	0.25	19.36	1.00	1.49	0.25	7.39	0.25	5.10	1.26
07.10.86	6.8	2.47	0.50	5.94	1.56	0.56	0.25	5.21	1.09	2.40	0.25	2.21	1.00	0.84	0.25	4.73	1.20	3.29	1.37
08.10.86	4.0	1.00	0.50	1.54	1.92	0.25	0.25	1.03	1.00	0.50	0.25	0.50	2.21	0.25	0.50	20.50	4.33	1.00	1.33

[a] Non-chlorinated and [b] chlorinated sample caused acute lethality to *Daphnia magna*

[c] Influent sample lethal to *Daphnia magna*

[d] Influent sample lethal to *Salmo gairdneri*

were measured in excess of reported LC50s in many cases but lethality did not always occur, therefore their roles in the expressed toxicity are uncertain. It is generally considered that contaminants present at less than 0.2 of their LC50 do not significantly contribute to acute lethality in a toxicant mixture(35,36). Cadmium, nickel and lead, were not likely important toxic contributors because measured concentrations were almost always less than 0.2 of respective documented 96-hour LC50 concentrations.

Among organics, only the influent xylene concentration of September 30 appears to be a probable source of toxicity to Daphnia since all other contaminants measured were well below acutely lethal levels. No effluent samples contained toxic levels of organics.

Most acutely lethal samples were taken during high waste load (high flow) conditions. This may be related to increased industrial input of some toxic contaminants which, in addition to high levels of ammonia, resulted in lethality to organisms.

5.4.5 Chronic Toxicity Tests

Comparison of Ceriodaphnia 7-day LC50 with 48-hour Daphnia LC50 (Table 60) suggests that Ceriodaphnia were more sensitive. However, review of 48-hour mortality data for both Daphnia and Ceriodaphnia shows that the effluents were nonlethal over that exposure period. The greater apparent sensitivity of Ceriodaphnia is clearly a result of longer exposure in this case. Ceriodaphnia 7-day LC50s were lower than either rainbow trout 96-hour and Daphnia 48-hour LC50s except for the October 5 "high flow" sample. However clinoptilolite treatment of that sample virtually eliminated toxicity to Daphnia suggesting that Ceriodaphnia are either more tolerant of ammonia and/or other cation toxicants than Daphnia.

The sublethal toxicity results of the four Galt STP chlorinated/treated effluent samples are presented in Tables 63, 64, 65 and 66. The chronic effect value is derived by calculating the geometric mean of the "no observed effect

Table 63

CERIODAPHNIA REPRODUCTIVE INHIBITION

Number of young produced by Ceriodaphnia exposed to Galt STP chlorinated/treated effluent collected on 05 October 1986 at 10:00 (high flow).

Ceriodaphnia		Effluent Concentration (% v/v)							
Replicates	Control	1	3	5	10	20	30	50	100
1	24	21	12	19	15	23	20	20	0
2	19	16	24	15	22	20	25	24	0
3	19	0	12	12	19	14	30	16	0
4	20	10	0	5	18	17	30	15	0
5	0	11	17	22	10	25	9	6	0
6	9	21	27	16	21	25	24	11	0
7	19	8	9	0	24	32	20	27	5
8	11	11	0	25	29	26	21	19	1
9	25	6	25	15	17	37	23	24	1
10	11	16	8	14	11	25	20	12	0
TOTAL	157	120	134	143	186	224(s)	222(s)	174	7*

NOEC = 50%
LOEC = 100%
Chronic Value = 71%

(s) Stimulatory effect $p < 0.05$.

* Significant reduction compared to control $p < 0.05$.

Table 64

CERIODAPHNIA REPRODUCTIVE INHIBITION

Number of young produced by Ceriodaphnia exposed to Galt STP chlorinated/treated effluent collected on 06 October 1986 at 10:00 (high flow).

Ceriodaphnia		Effluent Concentration (% v/v)							
Replicates	Control	1	3	5	10	20	30	50	100
1	13	3	0	19	18	17	8	6	0
2	23	15	14	14	19	9	14	6	0
3	26	0	16	4	11	16	11	5	0
4	15	20	14	14	20	15	11	0	0
5	22	14	18	15	1	5	6	0	0
6	16	5	9	0	26	9	8	6	0
7	0	18	9	0	22	15	11	7	0
8	15	6	8	12	20	0	13	0	0
9	19	5	15	16	0	13	7	5	0
10	27	17	5	21	16	18	13	7	0
TOTAL	176	105	108	115	153	117	102	42*	0

NOEC = 30%
LOEC = 50%
Chronic Value = 39%

* Significant reduction compared to control $p < 0.05$.

Table 65

CERIODAPHNIA REPRODUCTIVE INHIBITION

Number of young produced by Ceriodaphnia exposed to Galt STP chlorinated/treated effluent collected on 07 October 1986 at 04:00 (low flow).

Ceriodaphnia		Effluent Concentration (% v/v)							
Replicates	Control	1	3	5	10	20	30	50	100
1	14	19	20	22	5	24	29	24	0
2	15	13	16	21	20	24	19	14	0
3	0	23	0	13	18	36	15	23	1
4	14	21	15	28	0	24	29	27	0
5	20	25	25	20	27	31	26	19	4
6	14	13	23	27	16	28	38	25	0
7	23	7	20	14	10	32	31	16	0
8	23	24	22	17	17	42	29	17	0
9	0	8	16	24	25	29	28	22	0
10	14	9	14	17	20	30	32	34	2
TOTAL	157	162	171	203	158	300(s)	276(s)	221	7*

NOEC = 50%

LOEC = 100%

Chronic Value = 71%

(s) Stimulatory effect $p < 0.05$.

* Significant reduction compared to control $p < 0.05$.

Table 66

CERIODAPHNIA REPRODUCTIVE INHIBITION

Number of young produced by Ceriodaphnia exposed to Galt STP chlorinated/treated effluent collected on 08 October 1986 at 04:00 (low flow)

Ceriodaphnia		Effluent Concentration (% v/v)							
Replicates	Control	1	3	5	10	20	30	50	100
1	22	13	12	9	22	19	19	23	0
2	19	10	19	21	25	10	24	18	1
3	16	11	22	18	25	24	11	22	0
4	24	14	16	22	11	13	17	21	0
5	27	19	14	19	27	27	17	14	0
6	18	14	19	25	20	27	30	15	3
7	19	28	20	24	19	34	28	17	0
8	12	17	24	16	13	0	37	20	0
9	15	25	28	20	36	25	26	17	1
10	20	5	31	22	17	33	26	14	0
TOTAL	192	156	205	196	215	212	235	181	5*

NOEC = 50%
LOEC = 100%
Chronic Value = 71%

* Significant reduction compared to control $p < 0.05$.

concentration" (NOEC) and the "lowest observed effect concentration" (LOEC). The calculated chronic values for "low waste load" samples were both 71 percent; the "high waste load" chronic values were 71 percent to 39 percent (v/v).

In two cases, an intermediate stimulatory effect (increased production of young) was observed in the _Ceriodaphnia_ reproduction test. However, the chronic effect value was based on concentrations that resulted in reduced productivity of young.

Effluent concentrations inhibiting _Ceriodaphnia_ reproduction were lower than any of the LC50 values for rainbow trout and _Daphnia_, again except for the October 5 "high flow" sample. This clearly demonstrates the greater sensitivity of the _Ceriodaphnia_ reproductive response. Comparison of _Ceriodaphnia_ 7 day LC50 values with reproductive inhibition concentrations indicates the latter to be about 20 percent more sensitive (mean difference 0.18 ± 0.1 SD).

5.5 Prediction of Galt STP Influent Quality

As was the case for both the Waterloo and Welland STPs, the dry weather flow component of HAZPRED was used to predict the influent concentrations of selected metals and trace organics to the Galt STP. The industrial contributors were summarized in Table 13, based on data provided by the Regional Municipality of Waterloo. From these data and estimates of the commercial and domestic flow, concentrations of heavy metals and prevalent organic compounds were developed by HAZPRED. The organics which were included in the prediction were chloroform, toluene, benzene, trichloroethylene, ethylbenzene, tetrachloroethylene and 1,2-dichlorobenzene.

Table 67 compares the predicted and observed geometric mean concentrations for the selected compounds, in terms of the logarithmic ratio. All metals were predicted to within 0.5 logarithmic units with the exception of lead which was predicted to be almost an order-of-magnitude higher than observed (logarithmic ratio = -0.94). With the exception of copper, the predicted value was higher than the observed mean value.

Table 67
COMPARISON OF PREDICTED AND OBSERVED INFLUENT CONCENTRATIONS AT GALT STP

Contaminant	Concentration (µg/L) Observed	Predicted	Log Ratio
Chloroform	2.20	10.42	-0.68
Toluene	4.10	33.62	-0.91
Benzene	0.70	118.92	-2.23
Trichloroethylene	4.20	10.31	-0.39
Cadmium	3.50	8.53	-0.39
Chromium	56.30	106.12	-0.28
Copper	125.00	63.59	0.29
Lead	11.10	95.61	-0.94
Nickel	40.10	56.13	-0.15
Zinc	172.00	330.54	-0.28
Ethylbenzene	15.99	1.50	1.03
Tetrachloroethene	11.40	6.90	0.22
1,2-Dichlorobenzene	2.23	1.10	0.31

Similarly, for organic compounds, agreement between the observed and predicted values was generally within an order-of-magnitude. Exceptions were ethylbenzene, which was predicted to be significantly lower than observed, and benzene, which was predicted to be more than two orders-of-magnitude higher than observed.

In the case of the Galt STP, the average flow predicted by HAZPRED (29,023 m^3/d) was approximately twenty percent lower than the measured flow during the sampling period. Thus, the contaminant loadings predicted by HAZPRED would generally agree better with the observed values than the concentrations presented in Table 67 since concentrations were normally overestimated. A similar pattern was observed when HAZPRED was applied at the Waterloo STP.

6.0 DEVELOPMENT OF DYNAMIC MODELS

6.1 Modelling Approach

The technique of time series analysis was used to develop models describing the dynamic response characteristics of the full-scale wastewater treatment facility to changes in influent concentrations of selected metals and trace organics. Time series analysis, as described by Box and Jenkins(37), involves the development of relationships between an observed series of process outputs (Y_t) sequential in time and a similar series of process inputs (X_t). Predictive models called transfer function-noise models are developed and their statistical validity is verified using the Box-Jenkins' techniques. These models have the form:

$$Y_t = \frac{(\omega_0 - \omega_1 B - \omega_2 B^2 - \dots\dots\dots\dots - \omega_s B^s) B^b}{(1 - \delta_1 B - \delta_2 B^2 - \dots\dots\dots\dots\dots\dots - \delta_r B^r)} X_t + \frac{(1 - \theta_1 B - \dots\dots\dots\dots - \theta_q B^q)}{(1-B)^d \; (1 - \phi_1 B - \dots\dots\dots - \phi_p B^p} a_t$$

where: Y_t = system response (deviation from the mean) at time t,

X_t = system input (deviation from the mean) at time t,

δ, ω = transfer function model parameters,

r,s = transfer function model orders,

b = system delay period

B = backward shift operator, e.g. $B^n Y_t = Y_{t-n}$

θ, ϕ = noise model parameters,

p,d,q = noise model orders,

a_t = white noise sequence with zero mean and constant variance.

From the model parameters (δ, ω, b), it was possible to estimate the time required for the process to achieve a new steady state value after a step change in process input or the time to return to steady state after a shock load has been experienced (the response time) and the magnitude of the change in output from a known change in input concentration (gain). This is valuable information in the descriptive analysis of processes susceptible to inputs which are variable in time and in the design of management approaches to reduce the impact of variable or shock loads on a system.

Similar modelling approaches have been used to describe the non-steady state removal of conventional contaminants in activated sludge systems(38), rotating biological contactors(39) and biological fluidized beds(40).

Construction of the transfer function - noise models involved an iterative procedure to estimate model parameters and to test residuals to determine the adequacy of the model. The forms of the transfer function models were identified based on the cross-correlation between inputs and outputs of selected contaminants. The forms of the noise models were identified from the residuals of the fitted transfer function models. The parameters of the combined transfer function - noise models were estimated using nonlinear least squares regression and the model adequacies were verified by diagnostic checks on the final residuals.

Examination of the chronological data, the autocorrelation function (ACF) of the series of process inputs and the experience gained from initial fitting of tentative transfer function - noise models suggested that strong diurnal effects were present in the trace contaminant data. For example, Figure 126a shows the ACF for the influent tetrachloroethylene concentration series at the Galt STP. The ACF shows significant low-lag correlation and significant correlation in the vicinity of the 12th lag, corresponding to a 24 hour diurnal variation in concentration. Diurnal effects make transfer function - noise model identification difficult. Thus, a "seasonal" model as described by Box and Jenkins was used to "prewhiten" the input series. With the exception of a significant value at one high lag (16), prewhitening transformed the correlated input series to an uncorrelated white noise series as illustrated by the ACF of the prewhitened input residuals (Figure 126b). The seasonal model was used to transform the effluent concentration series prior to generation of the cross-correlation function (CCF) to facilitate transfer function model identification. Figure 126c shows the CCF between the prewhitened input series and transformed output for the sequence. The CCF shows two periods of delay prior to a significant response in the effluent due to an input perturbation followed by an additional significant value at lag 4. A first-order transfer function model of the form $(1 - \delta B)Y_t = \omega_o B^2 X_t$ was selected to represent the relationship between these series.

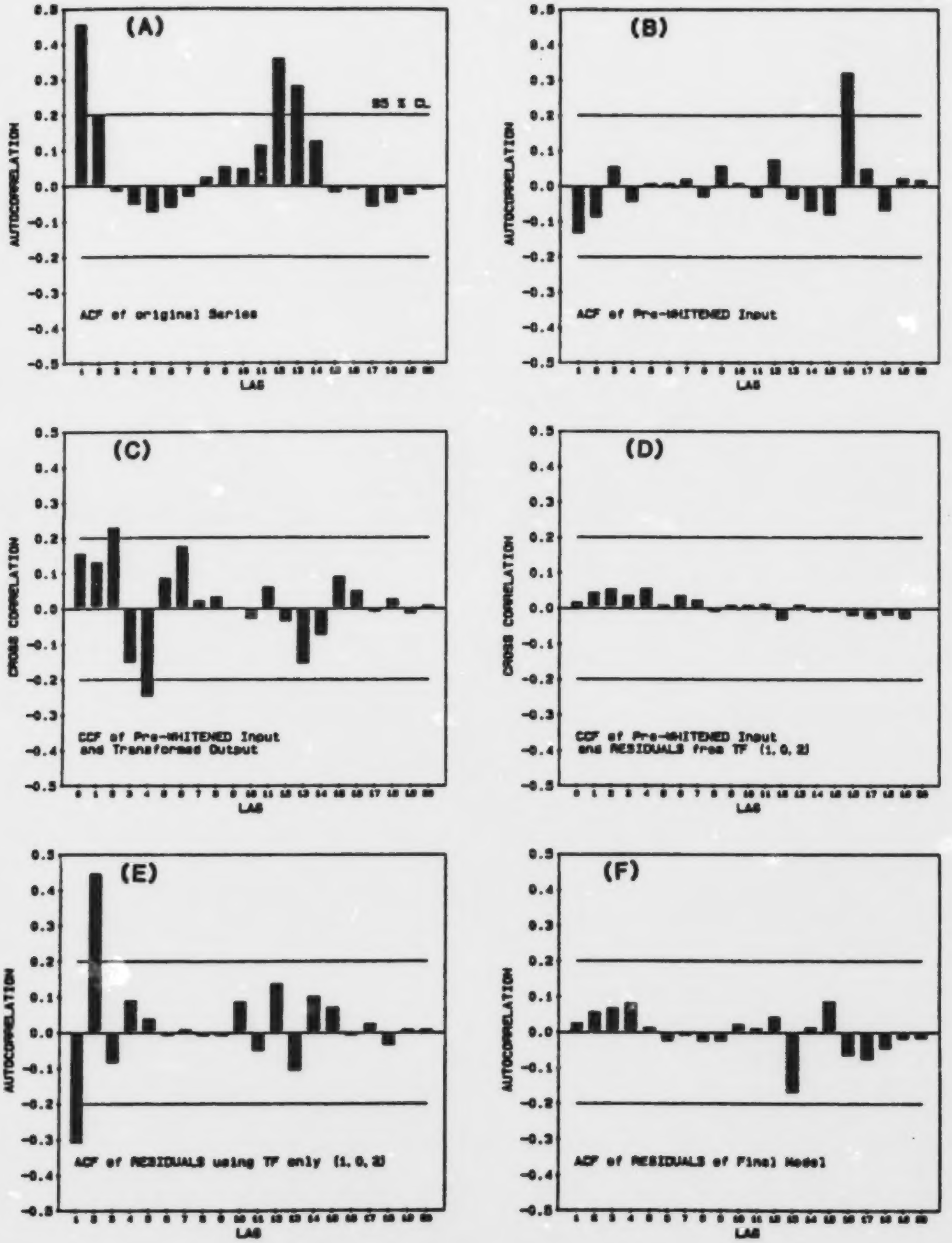

FIGURE 126 : AUTO AND CROSS CORRELATION FUNCTIONS FOR TETRACHLOROETHYLENE MODEL BUILDING (GALT STP)

The CCF between the residuals of this model and the prewhitened input indicated that the transfer function adequately described effluent variations cause by variations in the influent (Figure 126d). The ACF of the residuals of the pure transfer function model (Figure 126e) suggested that a second order moving average model was required to describe the noise term. Therefore, this noise structure was used to fit the combined transfer function - noise model for tetrachloroethylene. With this structure, the ACF of the residuals of the fitted combined model was not significant (Figure 126f) and, together with the CCF of the residuals of the combined model and prewhitened input, indicated that the model was adequate. Similar approaches were used to develop models for other trace contaminant concentration data which were presented in chronological form in Sections 3, 4, and 5 of the report.

6.2 Contaminants Included in the Models

Only contaminants which were detected in the treatment plant influents and effluents more than 90 percent of the time at concentrations above the detection limit and which exhibited a statistically significant cross-correlation between influent and effluent concentrations were selected for modelling. Of the contaminants which met these criteria, some of the metal species such as cadmium at the Welland STP and at the Waterloo STP, were consistently quantified at concentrations near the analytical detection limit where the resolution of the analytical method (±1 μg/L) would not allow dependable modelling. Because of the lack of information in these concentration sequences, significant models describing their dynamic behaviour could not be developed. Table 68 identifies contaminants whose influent and effluent concentration sequences contained adequate variability and cross-correlation to merit modelling. As is apparent from Table 68, the majority of the modelling was done on data collected at the Galt STP where contaminant concentrations were generally higher and more variable in both influent and effluent samples.

Table 68
TRACE CONTAMINANTS SUITABLE FOR DYNAMIC MODELLING

STP	Contaminant	Input (Independent) Variable
Galt	Copper	Influent Concentration
	Zinc	Influent Concentration
	Chromium	Influent Concentration
	Tetrachloroethylene	Influent Concentration
	1,4-Dichlorobenzene	Influent Concentration
	1,1,1-Trichloroethane	Influent Loading
Welland	Chromium	Influent Concentration
	Nickel	Influent Concentration
Waterloo	Zinc	Influent Concentration

6.3 Dynamic Models

The transfer function - noise models which were developed are presented in Table 69. The effluent concentrations were predicted from the influent concentration sequences with the exception of the 1,1,1-trichloroethane concentration sequence at the Galt STP which was found to be related to the influent loading rather than the influent concentration.

Of the trace contaminant models developed for the Galt STP, the effluent zinc and 1,1,1-trichloroethane responses were described by simple delayed first and zero order transfer function models and noise models which incorporated a term to describe the diurnal (12 lags or 24 hr) component of the data. The effluent copper and tetrachloroethylene transfer function models were also simple delayed first-order models but the noise terms did not require a diurnal component. The transfer function models developed for chromium and 1,4-dichlorobenzene were multiple input models which included a short delay term and longer delay term. In the case of chromium, the longer delay term (lag 9) may represent a diurnal effect not accurately defined by the data. In the case of 1,4-dichlorobenzene, the lack of a delay term (lag 0) suggests that a change in influent quality immediately produced a change in effluent quality. This is

Table 69
TRANSFER FUNCTION - NOISE MODELS FOR SELECTED TRACE CONTAMINANTS

STP	Parameter	Input Variable	Model Form[1]
Galt	Copper (Cu)	Concentration	$(Cu_e)t = (0.024 + 0.021\ B)B^2\ (Cu_i)_t + \frac{(1 - 0.997\ B)}{(1 - B)(1 - 0.822\ B)}\ a_t$
	Zinc (Zn)	Concentration	$(Zn_e)t = \frac{0.057\ B^2}{(1 - 0.784\ B)}\ (Zn_i)_t + (1 + 0.250\ B)(1 + 0.337\ B^{12})a_t$
	Chromium (Cr)	Concentration	$(Cr_e)_t = \frac{0.006\ B^2}{(1 - 0.892\ B)}\ (Cr_i)_t + (0.012 + 0.011\ B)B^9\ (Cr_i)_t + \frac{1}{(1 - 0.624\ B)}\ a_t$
	Tetrachloroethylene (TET)	Concentration	$(TET_e)_t = \frac{0.066\ B^2}{(1 - 0.663\ B)}\ (TET_i)_t + (1 + 0.169\ B + 0.488\ B^2)a_t$
	1,2-Dichlorobenzene (DCB)	Concentration	$(DCB_e)_t = 0.084\ (DCB_i)_t + (0.037 + 0.096\ B)B^3\ (DCB_i)_t + \frac{1}{(1 + 0.684\ B)}\ a_t$
	1,1,1-Trichloroethane (TCE)	Loading	$(TCE_e)_t = 2.571\ B^4\ (TCE_L)_t + \frac{(1 + 0.363\ B^{12})}{(1 + 0.400\ B)}\ a_t$
Welland	Chromium (Cr)	Concentration	$(Cr_e)_t = 0.0489\ B^3\ (Cr_i)_t + \frac{1}{(1 - 0.201\ B - 0.271\ B^2)}\ a_t$
	Nickel (Ni)	Concentration	$(Ni_e)_t = 0.0648\ B^{10}\ (Ni_i)_t + \frac{1}{(1 - 0.387\ B)}\ a_t$
Waterloo	Zinc (Zn)	Concentration	$(Zn_e)_t = \frac{0.0560\ B^6}{(1 - 0.844\ B)}\ (Zn_i)_t + \frac{1}{(1 - 0.414\ B)}\ a_t$

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[1] i = influent concentration
L = influent loading
e = effluent concentration

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physically unlikely given the retention time in the full-scale facility and may be an artifact associated with the limited data available for model development.

Models developed to describe the dynamic metal concentration responses at Welland and Waterloo were simple zero and first-order transfer function models and did not incorporate any diurnal characteristic in their noise model. The lag between input perturbation and output response varied from approximately 6 hours for chromium to 20 hours for nickel.

Key dynamic response parameters for these trace contaminants are summarized in Table 70, along with the standard deviation of the model residuals, which provides an indication of the ability of the model to fit the measured data. Overall, the addition of the noise model results in minimal improvement in the overall fit based on the standard deviation of the residuals. Comparing the standard deviation of the transfer function model residuals to the arithmetic mean effluent concentration for each parameter, the RSD ranges from approximately 13 percent for chromium to approximately 160 percent for TCE.

The time between the beginning of the influent perturbation and the beginning of the effluent response (lag time) for these contaminants varied between 4 and 20 h, exclusive of the questionable zero lag term in the 1,4-dichlorobenzene model. The dynamic response time of the system to the influent perturbations, reported as the first-order time constant (τ), was estimated only for tetrachloroethylene, zinc and chromium at the Galt STP and zinc at the Waterloo STP. The time constant, which represents the time required for the effluent to achieve 63.2 percent of its final steady state value after initiation of the response to a step change in influent conditions, varied from about 5 to 17 h for these contaminants compared to nominal plant HRTs of about 9 h. The steady state process gains, which indicate the magnitude of the effluent response to a unit change in the influent variable, were lower than the average removal efficiencies reported for these contaminants, suggesting that removal efficiency improved at higher influent concentrations. This may be an artifact of analyzing effluent data at close to detection limit values, however. In this situation, constant reported effluent values may result despite significant increases in the influent concentration.

Table 70
KEY DYNAMIC RESPONSE PARAMETERS FOR TRACE CONTAMINANTS

STP	Contaminant	Lag Time (h)	First-Order Time Constant (min)	Steady State Gain[1]	Standard Deviation of Model Residuals[3]	
					Overall	TF
Galt	Copper	4	No Estimate	0.045	7.53	7.88
	Zinc	4	493	0.265	33.90	42.33
	Chromium[2]	4, 18	1046	0.058, 0.023	3.48	3.68
	Tetrachloroethylene	4	292	0.196	11.34	13.74
	1,1,1-Trichloroethane	8	No Estimate	2.571	0.51	0.61
	1,4-Dichlorobenzene[2]	0, 6	No Estimate	0.084, 0.133	0.44	0.61
Welland	Chromium	6	No Estimate	0.049	1.6	1.7
	Nickel	20	No Estimate	0.065	2.1	2.3
Waterloo	Zinc	12	707	0.359	22.9	25.6

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[1] Steady-state gain reported in dimensionless units (μg/L)/(μg/L) except 1,1,1-trichloroethane (μg/L)/(kg/d).

[2] For chromium and 1,4-dichlorobenzene, lag times and gains are reported for each component of the transfer function model (refer to Table 69)

[3] Standard deviation reported in μg/L.

Figure 127 illustrates the ability of the dynamic models to fit the effluent concentrations based on the measured input to the Galt STP for a selected metal (copper) and organic compounds (tetrachloroethylene). In both cases, the measured effluent concentration sequence is presented along with the effluent concentration fitted by the transfer function model alone and the combined transfer function - noise model. In both cases, the transfer function model alone follows the trends in the effluent data. Some improvement in the overall model fit is achieved by the addition of the noise component. It should be noted that the comparison in Figure 127 does not represent model verification as these are the same data used to generate the model and not an independent data set.

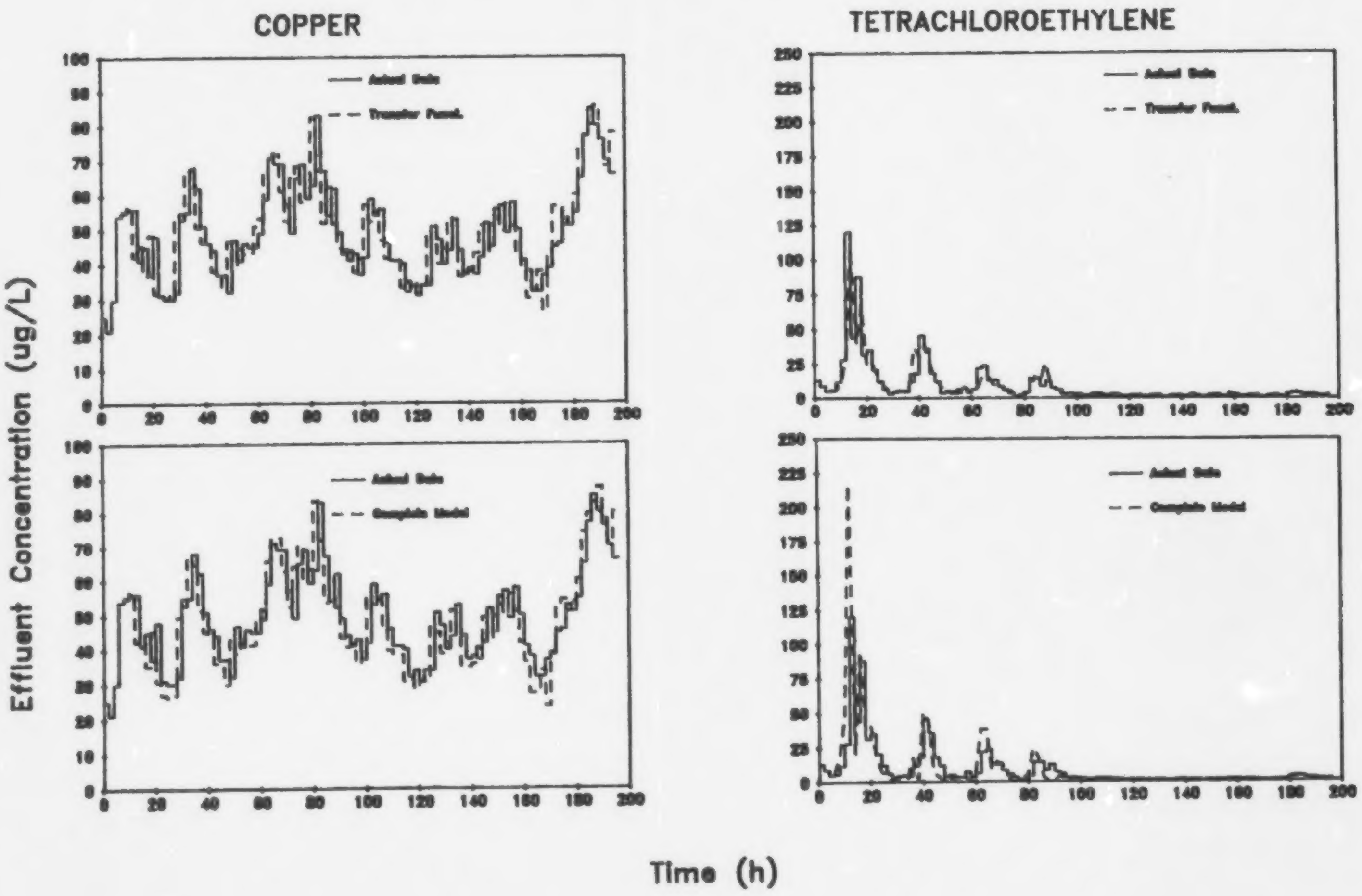

FIGURE 127 : COMPARISON OF MODEL WITH MEASURED EFFLUENT CONCENTRATIONS

7.0 SUMMARY AND CONCLUSIONS OF FIELD STUDIES

The influent and effluent quality at the three STPs included in the field sampling program are compared in this section of the report from the standpoint of concentrations, removal efficiency and variability. The implications of the toxicity testing and modelling activities are also discussed.

7.1 Influent and Effluent Concentrations of Trace Contaminants

Influent and effluent concentrations of heavy metals at the three sampled STPs are summarized in Table 71. It is noteworthy that the Welland STP, the municipal treatment plant selected to represent the heavily industrialized category, had the lowest concentration of every metal in its raw wastewater. On the other hand, the Waterloo STP, selected to represent a primarily domestic municipal facility, had the highest influent concentrations of cadmium and lead, and concentrations of other metals near those measured at the Galt STP. Influent concentrations of all contaminants at the Welland STP were significantly affected by sewage dilution as a result of extraneous flows in the collection system.

The Welland STP effluent also had the lowest concentrations of all metals monitored. Effluent concentrations at the Galt and Waterloo STPs were generally comparable with the exception of copper and nickel. In these cases, the effluent from the Waterloo STP had significantly lower concentrations than the effluent from the Galt STP. In all cases, cadmium and lead were present at lower concentrations in both influents and effluents than chromium, copper, nickel, and zinc.

Table 72 lists the organic compounds identified frequently in the influent and effluent samples at the three municipal STPs. Of the trace organics which were included in the analytical program, only six compounds including phenolics were consistently quantified in influents and effluents at all three STPs. Of these six compounds, two were aromatic hydrocarbons - toluene and p&m-xylene - and three were

Table 71
INFLUENT AND EFFLUENT CONCENTRATIONS OF METAL CONTAMINANTS

Geometric Mean Concentration (µg/L)

Metal	Influents Waterloo	Influents Welland	Influents Galt	Effluents Waterloo	Effluents Welland	Effluents Galt
Cadmium	4.4	2.7	3.5	4.1	2.4	2.2
Chromium	46.7	14.9	56.3	27.3	9.1	30.1
Copper	110.	30.9	125.	13.5	5.8	47.3
Nickel	26.0	14.4	40.1	23.8	13.0	48.1
Lead	13.6	8.3	11.1	5.7	5.3	5.3
Zinc	135.	64.9	172.	74.9	21.9	77.2

Table 72
TRACE ORGANIC COMPOUNDS AT MUNICIPAL STPs

Geometric Mean Concentration (μg/L)

Compound	Influents			Effluents		
	Waterloo	Welland	Galt	Waterloo	Welland	Galt
Total Phenolics	16.2	9.7	19.9	2.7	2.0	3.5
Benzene	1.4	-	0.7	0.3	-	0.3
Toluene	3.4	0.8	4.1	0.3	<0.5	0.3
p&m-Xylene	8.3	0.6	7.5	0.3	0.3	0.5
Chloroform	2.8	3.9	2.2	0.8	0.8	0.9
1,1,1-trichloroethane	1.1	-	5.0	0.6	-	2.0
1,4-dichlorobenzene	1.7	2.1	4.0	0.8	0.8	1.4
Trichloroethylene	1.3	1.0	4.2	0.5	<1.0	1.0
Ethylbenzene	-	-	1.5	-	-	0.3
Tetrachloroethylene	-	-	6.9	-	-	3.3
o-Xylene	-	-	3.2	-	-	0.4

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chlorinated volatile organics - chloroform, 1,4-dichlorobenzene and trichloroethylene. With the exception of total phenolics, none of the organic compounds were found at a mean concentration in excess of 10 µg/L. The Galt STP contained the greatest number of organic compounds in the influent and effluent streams, followed by the Waterloo STP and the Welland STP.

Polyaromatic hydrocarbons were generally not found in the influents or the effluents at any of the STPs sampled. At the Waterloo STP, only phenanthrene was quantified at trace levels or greater in more than 50 percent of influent and effluent samples. Phenanthrene was also commonly quantified at the Welland and Galt STPs, along with fluorene.

7.2 Removal of Trace Contaminants in Municipal STPs

Table 73 compares the removal efficiency of heavy metals across the three municipal STPs, based on the influent and effluent geometric mean concentrations.

Table 73
REMOVAL OF HEAVY METALS IN MUNICIPAL STPs

Metal	Percent Removal at STP		
	Waterloo	Welland	Galt
Cadmium	6.8	11.1	37.1
Chromium	41.5	38.9	46.5
Copper	87.7	81.2	62.2
Nickel	8.5	9.7	0.
Lead	58.1	35.1	52.2
Zinc	44.5	66.3	55.1

The removal efficiencies measured generally agree with values reported elsewhere in the literature(4), and the relative order of the metals in terms of increasing removal efficiency is consistent with other data(4). Nickel was generally removed with the lowest efficiency. Copper and zinc were the metals most effectively removed in the municipal STPs. The low removal efficiency reported for cadmium at the Waterloo and Welland STPs relates to the low influent concentrations. Removals were generally lower at the Galt STP than at the other two facilities, possibly due to the higher concentrations of suspended solids in the effluent at Galt than at the other two plants.

Removal data for organic contaminants at the three municipal STPs are summarized in Table 74, based on geometric mean concentrations.

Table 74
REMOVAL OF TRACE ORGANICS IN MUNICIPAL STPs

Organic	Percent Removal at STP		
	Waterloo	Welland	Galt
Total Phenolics	84	79	82
Benzene	79	-	57
Toluene	91	>38	93
p&m-Xylene	90	50	93
Chloroform	71	79	59
1,1,1-trichloroethane	45	-	60
1,4-dichlorobenzene	53	60	65
Trichloroethylene	60	-	76
Ethylbenzene	-	-	80
Tetrachloroethylene	-	-	52
o-Xylene	-	-	88

Removals generally exceeded 50 percent and were near 90 percent for most aromatic hydrocarbons. In many cases, the removal efficiencies were somewhat lower than reported elsewhere(4) because of the low concentrations present in the raw wastewaters.

7.3 Variability of Trace Contaminants

At all three STPs, the effluents were less variable in concentration than the influents for all categories (conventionals, metals, organics) of contaminants based on the normalized variance of selected compounds in each category. The variability of the metal concentrations in the Galt STP influent was significantly greater than that of the other two STPs as a result of some high influent peaks. At the other two plants, metals and conventional contaminants exhibited a similar degree of variability.

In all cases, organic contaminants had a greater degree of variability in the effluents than metals or conventional contaminants. Metals as a group were more variable than conventionals in the effluents from all three STPs.

Table 75 identifies the contaminants in influents and effluents at each STP which were found to exceed the variability criterion (95th percentile concentration exceeds geometric mean by a factor of 2.0) established for the study. With the exception of filtered phosphorus, none of the conventionals exceeded the criterion in the effluent although FOC and TSS were generally found to be variable in the raw wastewaters. Filtered phosphorus concentrations at both the Waterloo STP (loss of chemical feed) and at the Galt STP (experimentation with ferrous chloride) were affected by exceptional circumstances.

Of the trace metals, chromium, lead and zinc concentrations exceeded the variability criterion in the influent stream at all three STPs and all metals exceeded the criterion in influent samples at the Galt STP. None of the metals exceeded the criterion in effluent samples at all three STPs.

Total phenolics, chloroform, toluene and p&m-xylene consistently exceeded the variability criterion in influent samples, but only total phenolics exceeded the criterion in all three STP effluents.

7.4 Toxicity of STP Influents and Effluents

A summary of the results of toxicity testing is presented in Table 76. A detailed literature review dealing with toxicity testing and reported lethal limits for a variety of trace contaminants is incorporated in Appendix II.

Table 75
CONTAMINANTS EXCEEDING VARIABILITY CRITERION

Influents			Effluents		
Waterloo	Welland	Galt	Waterloo	Welland	Galt
FOC	FOC				
TSS	TSS	TSS			
		Filt. P	Filt. P		Filt. P
	Cadmium	Cadmium			Cadmium
Chromium	Chromium	Chromium	Chromium		
Copper		Copper		Copper	
		Nickel			Nickel
Lead	Lead	Lead	Lead		
Zinc	Zinc	Zinc	Zinc		Zinc
Phenols	Phenols	Phenols	Phenols	Phenols	Phenols
Benzene					
Chloroform	Chloroform	Chloroform	Chloroform		Chloroform
1,1,1-trichloroethane			1,1,1-trichloroethane		
Toluene	Toluene	Toluene			Toluene
p&m-xylene	p&m-xylene	p&m-xylene	p&m-xylene		p&m-xylene
1,4-dichlorobenzene					
trichloroethylene	trichloroethylene				
phenanthrene			phenanthrene		
		Ethylbenzene			Ethylbenzene
		o-xylene			o-xylene
		tetrachloroethylene			tetrachloroethylene

Table 76

SUMMARY OF RESULTS FROM TOXICITY TESTS OF EFFLUENTS FROM GALT, WATERLOO AND WELLAND STPs

Species	Effluent Type	Test Type	No. Samples Tested	No. Lethal Samples	LC50 Range (%)
Galt					
Daphnia	Raw Waste	Acute LC50	17	2	16 to G 100
Salmo	Raw Waste	Acute LC50	4	2	56 to 63
Daphnia	Secondary, Non-chlor.	Acute LC50	17	1	84 to G 100
Daphnia	Secondary, Chlor.	Acute LC50	17	2	66 to G 100
Ceriodaphnia	Secondary, Chlor.	Chronic LC50	2	1	76 to G 100
Ceriodaphnia	Secondary, Chlor.	Chronic EC50	2	2	71
Ceriodaphnia	Secondary, Non-chlor.	Chronic LC50	2	2	46 to 88
Ceriodaphnia	Secondary, Non-chlor.	Chronic EC50	2	2	39 to 71
Waterloo					
Daphnia	Raw Waste	Acute LC50	10	5	9 to G 100
Salmo	Raw Waste	Acute LC50	4	3	38 to G 100
Daphnia	Secondary, Non-chlor.	Acute LC50	10	0	G 100
Salmo	Secondary, Non-chlor.	Acute LC50	4	0	G 100
Daphnia	Secondary, Chlor.	Acute LC50	13	0	G 100
Salmo	Secondary, Chlor.	Acute LC50	4	0	G 100
Welland					
Daphnia	Raw Waste	Acute LC50	10	1	71 to G 100
Salmo	Raw Waste	Acute LC50	4	4	71 to 95
Daphnia	Secondary, Non-chlor.	Acute LC50	10	0	G 100
Salmo	Secondary, Non-chlor.	Acute LC50	4	0	G 100
Daphnia	Secondary, Chlor.	Acute LC50	11	4	8 to G 100
Daphnia	Secondary, Dechlor.	Acute LC50	4	1	25 to G 100
Salmo	Secondary, Chlor.	Acute LC50	4	0	G 100

G = greater than.

Two out of 17 influent samples from Galt STP were lethal to Daphnia, while two of four were lethal to rainbow trout. Two of 17 and one of 17 effluent samples were lethal to Daphnia after secondary treatment and chlorination, respectively. The toxicity of the secondary treated waste samples was not obviously different from the influent samples. High waste loading conditions tended to increase the occurrence of lethality.

Ammonia appeared to represent the major toxicant for trout, but other contaminants were likely important contributors to Daphnia lethality. Copper, zinc and xylene were possible toxic agents. No single contaminant could account for all the observed lethality. Chlorinated effluent samples were not consistently different in their toxicity compared to non-chlorinated effluent samples. This was probably due to total residual chlorine (TRC) dissipation during aeration of the samples in the test.

Daphnia and trout demonstrated inconsistent sensitivity to toxic effluents. This was probably due to the variety of contaminants, the variation of their concentrations among samples, and the inherent difference in sensitivity of trout and Daphnia to specific contaminants. Sublethal tests with Ceriodaphnia were more sensitive measures of effluent toxicity than lethal tests.

Five out of ten influent samples from Waterloo STP were lethal to Daphnia, while three of four were lethal to trout. LC50's ranged from nine to 84 among lethal samples. Lethality was more frequent during high load conditions.

Ammonia was not measured in the influent samples from Waterloo so its role in influent toxicity is unknown. Copper and zinc levels were within the ranges of documented LC50's for rainbow trout and Daphnia. All measured contaminants (TRC, NH_3, metals, organics) in the secondary effluent were below levels reported to be lethal to trout and Daphnia. The effluent samples were not lethal to either species following secondary treatment (14 samples), nor after chlorination (18 samples).

No clear relationship was demonstrated between the relative sensitivities of rainbow trout and Daphnia. This is due to the changing chemical composition of the effluents and differences in inherent sensitivity of the species of particular chemicals.

Only one of ten influent samples from Welland STP was lethal to Daphnia (71 percent), while all four influent samples tested with rainbow trout were acutely lethal (71 to 95 percent). No prechlorination secondary effluents were acutely lethal to either species, but four post-chlorination samples resulted in Daphnia LC50's of 8 to 21. More acutely lethal samples were generated during high load than low load conditions.

Ammonia was identified as a likely source of rainbow trout lethality in influent samples. The ammonia levels measured were well below lethal levels for Daphnia, indicating that other contaminants must have been present. Copper and zinc were measured at sufficient levels to have contributed to lethality in both species. The assessment of chlorination effects on effluent toxicity was complicated by TRC dissipation from the test vessels and the poor detection limits of the analytical method. Some degree of toxicity was attributed to the presence of TRC.

Overall, it was found that ammonia was frequently identified as a source of organism lethality. Some chlorine toxicity was also demonstrated, but the test protocol (ie. static, with aeration) leads to chlorine dissipation and inaccurate reflection of its potency. Other contaminants contributed to toxicity in some STP effluents, such as metals, and may have been related, in part, to the proportion of industrial inflow to the STP. Chemical analyses alone would not provide a reliable estimate of STP effluent toxicity since, even when toxicants were measured at concentrations reported to be lethal, effluents were not always lethal to Daphnia or trout. Rainbow trout and Daphnia differ in their sensitivity to STP effluents, indicating that neither should be used as a surrogate for the other in toxicity assessment of effluents. Sublethal and chronic testing provided a more sensitive measure of effluent toxicity than did tests of acute lethality. The frequency of acutely lethal effluent samples was elevated during high wastewater loading to the

STPs (10:00 a.m. to noon), as compared to low loading conditions (4:00 a.m.). Based on these results, it appears that the process operating efficiency of an individual plant largely determines effluent toxicity with some influence resulting from the quantity of industrial inflow.

7.5 Modelling of Trace Contaminant Dynamics

The results of the time series analysis allow the prediction of the response of a complex process to an influent perturbation without total knowledge of the reactions and removal mechanisms occurring in the process. From the models developed, STP supervisors can predict the response of the effluent concentration to a known or anticipated change in influent characteristics, as illustrated for a hypothetical influent perturbation in Figure 128 for tetrachloroethylene.

As shown in Figure 128(c), the delay time before the change in effluent quality occurs is predicted by the transfer function component of the dynamic model, as well as the maximum concentration reached in the plant discharge. Based on these models, regulators can define the maximum acceptable concentration disturbances and durations which can be tolerated in the plant influent consistent with receiving water quality constraints. This information can be used to assist in the development of sewer use bylaws to manage trace contaminant discharges to wastewater treatment facilities. Knowledge of the dynamic response characteristics of the process can also provide plant designers with alternatives to mitigate the magnitude of the effluent response by alternatives such as increased HRT or offline concentration equalization.

However, it must be understood that there is considerable random variation in the concentration of these trace contaminants in STP effluents. The overall response of the STP to the pulse input of tetrachloroethylene is shown in Figure 128(b) based on the total transfer function-noise model. The delay time is consistent with that predicted by the transfer function alone and the magnitude of the response is similar; however, the random variation which is unrelated to influent quality is apparent. In the case of many of the trace contaminants measured in this program, the effluent concentration patterns were totally random as no discernible correlation to the influent concentration was identifiable.

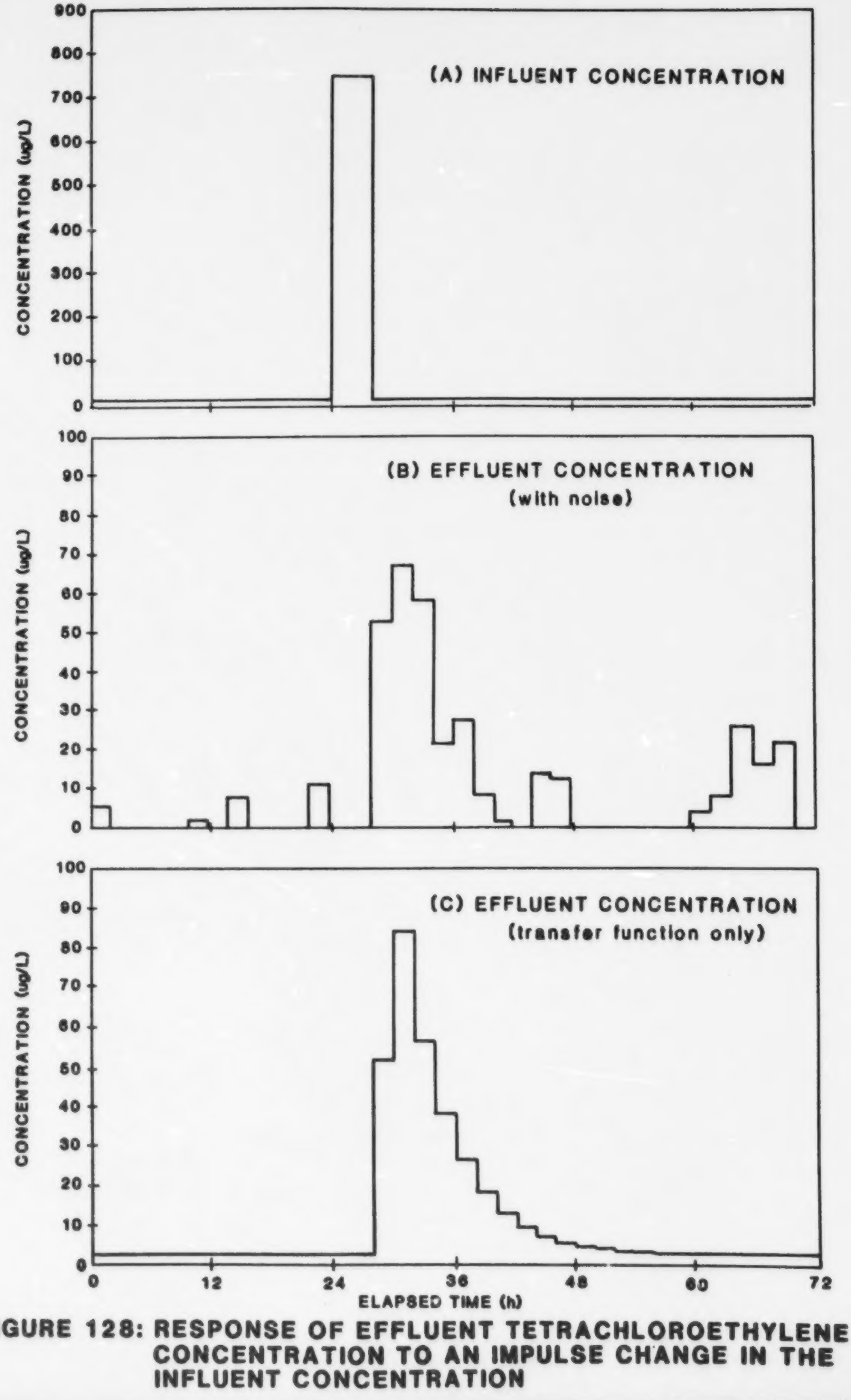

FIGURE 128: RESPONSE OF EFFLUENT TETRACHLOROETHYLENE CONCENTRATION TO AN IMPULSE CHANGE IN THE INFLUENT CONCENTRATION

This was also true of some conventional contaminants. Knowledge of the noise component of the effluent response improves the quality of the model and the ability to predict the effluent response. It is also essential that the impact of the noise component on the measured effluent concentrations be adequately considered in the development of effluent sampling requirements and the application of effluent quality criteria.

Predictive models such as those described here can be valuable tools in developing strategies for the control of trace contaminants in STPs; however, the ability of the dynamic models to accurately predict process response is a function of the adequacy of the data used for model identification and construction. It is necessary that the variation in the input and the output sequences are large, relative to the variation in the noise, and that a large amount of data is available. In this full-scale investigation, there was no ability to control the influent quality to ensure that an adequate response was achieved. In such cases, only a simple delayed first-order model can be justified by the data and only rough estimates of the model form may be possible. Further research is needed to refine these models and to assess their universality for the prediction of the dynamic response characteristics of trace contaminants.

7.6 Conclusions

Based on the results of the full-scale STP field sampling program, the following conclusions regarding the variability of trace contaminants in municipal sewage treatment plants are valid:

- Heavy metals, with the exception of cadmium, were typically found at concentrations in the 10 to 200 μg/L range in influents to the three STPs and were generally reduced to the 5 to 50 μg/L range in the treated effluents.

- Of the trace organics included in the analytical program, only six compounds (phenolics, toluene, xylenes, chloroform, 1,4-dichlorobenzene and trichloroethylene) were consistently quantified in influents and effluents at all three STPs. With the exception of phenolics, none of these compounds was found at mean concentrations in excess of 10 µg/L. PAHs were generally not found in the influents or effluents at any of the STPs sampled.

- Effluents were less variable in concentration than influents for all categories of contaminants (conventionals, metals, organics). Metals and conventional contaminants exhibited a similar degree of variability in influents but were less variable than organics. In effluents, organics were more variable than metals which were more variable than conventional contaminants.

- Based on examination of a wide range of trace contaminant data (metals, volatile organics, PAHs and total phenols) collected during this investigation, it was found that municipal STPs were capable of efficient trace contaminant removal and that the treatment processes at the three STPs sampled significantly attenuated the variability identified in the raw influent.

- For selected trace contaminants, perturbations in the influent characteristics produced significant responses in the effluent concentration.

- Time series models were developed to describe the responses of full-scale STPs to perturbations in the influent characteristics for selected trace contaminants. These models provide useful information for the management of trace contaminants in sewage collection systems and treatment facilities.

- Daphnia and trout demonstrated inconsistent sensitivity to toxic effluents. Ammonia appeared to represent the major toxicant for trout while other contaminants, possibly copper, zinc and xylenes, were likely important contributors to Daphnia lethality. Sublethal tests with Ceriodaphnia were more sensitive measures of effluent toxicity than lethal tests. Chemical analyses alone did not provide a reliable estimate of STP effluent toxicity.

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APPENDIX I

COMPARISON OF GC-MS AND GC ANALYSES OF VOLATILE ORGANICS

TABLE 1

SUMMARY OF QA/QC DATA FOR PURGEABLE COMPOUNDS FROM WATERLOO WPCP INTENSIVE MONITORING PROGRAM (JULY 2-10, 1986)

PURGEABLE COMPOUNDS	ANALYSIS BY GC/MS			ANALYSIS BY GC			SIGNIFICANCE BETWEEN DATA PAIRS(1)
	NO. POSITIVE DETECTIONS	NO. TRACE DETECTIONS	MEAN CONC'N IN PAIRED DATA (ug/L)	NO. POSITIVE DETECTIONS	NO. TRACE DETECTIONS	MEAN CONC'N IN PAIRED DATA (ug/L)	
Dichloromethane	55	0	29.4 ± 38.5*	55	0	36.8 ± 39.3	NS
T-1,2-Dichloroethylene	0	0		0	0		
1,1-Dichloroethane	1	4		0	0		
Chloroform	32	14	2.29 ± 3.58	33	5	2.53 ± 4.22	NS
1,2-Dichloroethane	0	0		0	0		
1,1,1-Trichloroethane	39	7	1.80 ± 1.14	24	1	1.13 ± 1.71	0.05
Benzene	24	3	2.22 ± 3.55	25	2	1.66 ± 1.86	NS
Carbon tetrachloride	0	0		0	0		
1,2-Dichloropropane	0	0		0	0		
Bromo dichloromethane	0	0		0	0		
Trichloroethylene	1	17		8	2		
1,3-Dichloropropene (z)	0	0		0	0		
1,3-Dichloropropene (e)	0	0		0	0		
1,1,2-Trichloroethane	0	0		0	0		
Toluene	24	2	5.32 ± 10.42	25	10	4.96 ± 10.90	NS
Dibromochloromethane	0	0		0	0		
Tetrachloroethylene	5	18		8	8		
Chlorobenzene	2	0		2	0		
Ethyl benzene	17	10		19	8		
p & m Xylene	24	4	9.75 ± 17.34	27	7	13.9 ± 23.8	0.05
Bromoform	0	0		0	0		
o-Xylene	24	1		22	4		
1,1,2,2-Tetrachloroethane	0	0		0	0		
1,3-Dichlorobenezne	0	0		0	0		
1,4-Dichlorobenzene	32	22	1.60 ± 1.69	17	17	0.90 ± 1.55	0.01
1,2-Dichlorobenzene	15	18		5	9		

(1) NS = Not Significant at 0.05 level
0.05 = Significant 0.05 level
0.01 = Significant at 0.01 level

* Arithmetic Mean ± Standard Deviation (includes both influent and effluent conc'ns)

APPENDIX II

BIOMONITORING PROCEDURES AND TECHNICAL REVIEW

1.0 INTRODUCTION

The Ontario Ministry of the Environment has implemented a Municipal and Industrial Strategy for Abatement (MISA) of contaminant discharges to receiving waters in the province. The two approaches being used to set effluent limits in the MISA program are based on best available technology (BAT) and receiving water quality impact. The focus of this study describes the toxicity of three municipal sewage treatment plant effluents (Galt, Waterloo and Welland). The toxicity testing represents a first estimate of what biological impact would result when the effluent is discharged to the receiving water. Once a sufficiently broad profile of effluent toxicity has been established for STPs, then minimum toxicity performance limits can be set for the final effluents, and would be considered achievable by all plants.

Each of the three plants in the study was a secondary treatment facility selected for the representative nature of characteristic inputs (e.g., residential, industrial, or mixed industrial-residential). Multiple composite samples were collected from the untreated raw influent, pre-chlorination secondary effluent, and post-chlorination final effluent streams during both high and low wastewater loading conditions. Organic and inorganic contaminants were measured in each of the samples (CANVIRO), and selected samples were evaluated for toxicity (BEAK).

1.1 Measurement of Effluent Toxicity

The term "toxicity" refers to a wide range of biological responses, all of which represent impairment to the normal functioning of an organism or a community. A toxic response in organisms results from a critical exposure to chemicals, compounds or a change in the physical environment. When toxic levels of contaminants are discharged from municipal or industrial sources, they often occur in the presence of other toxicants. Frequently, the presence of one contaminant increases or decreases the toxic effect of another contaminant in an effluent. The interactions among toxicants will be as numerous as the number and combinations of contaminants in a mixed effluent. Therefore, knowing toxicant, concentrations and the period of exposure alone is insufficient to precisely predict final toxicity, because the individual interactions of the toxicants are rarely quantified.

The simplest way to estimate the toxicity of a liquid effluent in a receiving water is to conduct a toxicity test using standard test organisms according to a standard test protocol. The organisms used are representative of those expected to inhabit the receiving water, e.g., fish, invertebrates and algae. The organism responses monitored to determine toxicity include lethality, impaired growth, impaired reproduction or impaired physiological function. While laboratory tests can only estimate the toxic impact of an effluent in a receiving water, they are more economical than similar tests that might alternatively be conducted in the actual receiving water using indigenous organisms.

The toxicity test takes the guessing out of estimating the toxicity of individual compounds and the interaction with other chemicals. The results are expressed as the effluent concentration or dilution required to produce a response in half (50%) of the exposed population, and/or the highest concentration that produces no-effect in the exposed population (threshold concentration; NOEC - the highest "no observed effect concentration").

The most frequent first-evaluation of a toxicant is the determination of the LC50. This is the concentration which causes lethality in 50% of the organisms tested, or the concentration which will kill an average or typical test organism, within a specified time period. Usually, a 96-hour test is used to determine the "acute" or short-term effects on fish and macroinvertebrates, while a slightly shorter period, typically 48 hours, is used for smaller organisms (e.g., Daphnia). "Chronic" tests are used to measure long-term effects on organisms, and show effects on growth, reproduction, behaviour, etc. and while not directly lethal to individuals would contribute to the demise or lack of competitive vigour of a community and, therefore, result in delayed lethality and/or ecosystem impairment. When responses other than lethality are measured, the concentration which causes a response in 50% of the test organisms is called the EC50 (concentration effective to 50% of exposed organisms).

Toxicity is measured by placing a suitable number of test organisms in effluent diluted with culture water or receiving water in a number of geometric dilution preparations. The percentage of organisms showing the indicated response is then plotted on a probit or probability scale against the concentration on a logarithmic scale. A line of best fit is estimated or calculated, and the 50% effect concentration (including confidence intervals) is determined.[7]

1.2 Application of Effluent Toxicity Tests

To define the degree of impact of an effluent on the receiving environment requires a test of the total, rather than individual, effects of all contaminants present. A toxicity test will express all of the toxicant actions and interactions of an effluent on a selected organism. If the intention is to prevent reproductive impairment of fish, for example, sublethal toxicity tests of reproduction can be conducted on a representative species to determine the dilution required by the receiving water before toxic effects disappear. Receiving water characteristics (volume, flow, etc.) will define the dilution profile of the effluent. Thus, the acceptability of the effluent can be determined based on the distance and area downstream that effects are likely to be observed. Assessment of receiving water quality based solely on compliance with a limited number of existing PWQO's is inadequate for a comprehensive evaluation of effluent impact. Biological tests must be included in a water quality assessment profile.

Toxicity tests are therefore used to quantify the cumulative toxicity of an effluents' component parts. The result is expressed as the effluent concentration that produces an effect in a representative, sensitive test species and can be compared with the dilution profile developed for each receiving water site. This study represents a first intensive evaluation of sewage treatment plant effluent acute and chronic toxicity.

2.0 BIOASSAY METHODS

2.1 Daphnia Acute Lethality Testing Procedure

Toxicological evaluation of effluent samples collected from the Galt sewage treatment plant were completed with Daphnia magna following the general directions of the EPA (1985) testing protocol. Suggested procedures specific for Daphnia testing by Buikema et al. (1980) were incorporated.

2.1.1 Culture Conditions

Daphnia magna were obtained from monoculture stocks at the Canadian Centre for Inland Waters, Great Lakes Biolimnology Laboratory in Burlington, Ontario. Taxonomic verification was completed using an invertebrate key (Pennak, 1953), by BEAK taxonomic specialists.

Daphnia stocks were fed a mixed solution of Selenastrum and Chlorella algae every 48 hours in glass culture aquaria containing laboratory dilution water held at $20 \pm 1^{\circ}C$. The photoperiod was maintained at 12 hours light, 12 hours dark. Water for culture was dechlorinated Mississauga tap water (Table 1) which is chemically analyzed monthly for specific conventional, inorganic and organic parameters.

The Daphnia culture was actively reproducing and no ephippial eggs (which develop when the culture is under stress from food deprivation, overcrowding, low temperature) had been generated since the culture was initiated. Based on general observations over the preceding 12 to 14 months, four to six young were being produced per adult in the stock culture.

2.1.2 Testing Procedure

Gravid adults selected from the stock culture were isolated in 50 mL vessels containing laboratory dilution water one to two days prior to testing (Table 1) and 24- to 48-hour old neonates were collected for the bioassays. Different adults provided neonates for definitive tests.

The definitive tests were completed using neonates generated as described above. The effluent exposure concentration series were as follows: 5,10,20,30,50 and 100%. Additional lower effluent concentrations were prepared after 24 hours if preliminary results indicated that the samples were toxic in the lowest test dilution.

The bioassays were conducted in 200 mL glass containers. The test volume was 100 mL, and the sample was not aerated. Each test vessel contained ten daphnids. Each test was accompanied by a control containing dilution water only, but was subjected to the same test conditions as the effluent concentrations.

All tests were conducted at a temperature of 21±1°C under a controlled light regime (12 hours light/12 hours darkness). The test conditions are summarized in Table 2.

Dissolved oxygen, pH, temperature and conductivity were recorded prior to and after bioassay duration to ensure that physical test conditions were adequate for Daphnia survival and that dilutions were correctly prepared. All samples were aerated throughout the tests. Daphnia mortality was recorded at 24 and 48 hours, and the 48-hour median lethal concentrations (LC50) values and 95% confidence limits were determined by moving average method (Bennett, 1952).

2.2 Rainbow Trout Acute Lethality Test

The tests conducted were 96-hour static acute toxicity bioassays performed according to the procedure outlined in the Ontario Ministry of the Environment's "Protocol to Determine the Acute Lethality of Liquid Effluents to Fish" (MOE, 1983).

2.2.1 Culture Conditions

The fish obtained for these bioassays were juvenile rainbow trout with a mean weight of 1.2 g and a mean length of 51 mm. The fish were certified disease-free and obtained from Aquafarms, Feversham, Ontario. The fish were acclimated in the BEAK, Mississauga laboratory in a holding tank at a water temperature of 15±1°C for 14 to 23 days before testing. Holding and dilution water quality is presented in Table 1.

2.2.2 Testing Procedure

The test solutions were aerated during the period of exposure to maintain the concentration of dissolved oxygen above 8 mg/L. A fish loading rate of 0.6 L of test solution/g of fish/day was maintained throughout the exposure period. Ten fish were exposed per concentration tested. The bioassays were conducted in 30 L non-toxic plastic containers, each containing 30 L of solution, held at a constant temperature of $15\pm1^{\circ}C$. A photoperiod of 12 hours light/12 hours darkness was maintained during testing. The tests were accompanied by a control in which the fish were exposed to dechlorinated Mississauga tap water under the same test conditions. The specific conditions of the bioassays are presented in Table 3. Dissolved oxygen, pH, conductivity, temperature and fish survival were monitored daily in each test container at time 0, 24, 48, 72 and 96 hours.

Acute lethality (96-hour LC50) and 95% confidence limits were calculated by moving average according to Bennett (1952).

2.3 Ceriodaphnia Survival and Reproduction Sublethality Test Procedure

The sublethal toxicity of four effluent samples collected from the Galt sewage treatment plant was measured using the daphnid, Ceriodaphnia reticulata, following the EPA (1985) test method.

2.3.1 Culture Conditions

Ceriodaphnia reticulata were obtained from U.S. EPA, Duluth Research Laboratory monoculture stocks. Taxonomic verification was completed using an invertebrate key (Pennak, 1953) by BEAK taxonomic specialists. Ceriodaphnia stocks were fed daily a suspension of combined solution of fermentated trout chow, Fleischman's yeast and Cerophyl^{R} (powdered, dried cereal leaves). The feeding rate was 5 mL/L of culture medium. The culture stocks were maintained in 25 L glass aquarium, containing laboratory dilution water at $25\pm1^{\circ}C$. The photoperiod was 16 hours light, 8 hours dark at the 100 ft-C light intensity. The culture populations were maintained at a loading rate of less than 1,000 animals/L of medium to prevent crowding and to discourage gametogenesis.

Brood animals containing eggs selected from the stock culture were isolated in 50 mL beakers containing 15 mL of dilution water and 0.1 mL of food suspension for 24 hours prior to testing. After one day, the young produced and media were discarded, and brood females were transferred to fresh solution, and the resulting young produced within the following four hours were used as the test organism.

2.3.2 Survival and Reproduction Test Procedure

The definitive tests were completed using 4-hour-old Ceriodaphnia instars generated as described above. The tests were commenced within 72 hours of sample collection. The exposure concentration series were as follows: 1, 3, 5, 10, 20, 30, 50 and 100%. Ten animals were exposed to each effluent concentration, and only one animal was placed in each exposure vessel. The bioassays were conducted in 40 mL polyethylene vessels with 15 mL of test solution. Each bioassay was accompanied by a control containing dilution water only, but subjected to the same test conditions as the effluent concentrations.

All tests were conducted at $25 \pm 1^{\circ}C$ under the same photoperiod as the stock culture. All organisms in the test vessels were fed daily at a rate of 0.1 mL food suspension/15 mL of test solution (Table 4). Each surviving test organism was transferred daily into a new test vessel containing 15 mL of freshly prepared test solution and 0.1 mL of the food suspension. Once the individual Ceriodaphnia had matured and were producing young (on about the third day), only the adult was transferred to fresh effluent solution and fed. The remaining young were sacrificed with two drops of 1N HCl and counted. Dissolved oxygen, pH, temperature and conductivity were recorded at the beginning and end of each 24-hour exposure period in each test concentration and control.

The adult survival and number of young produced were recorded daily.

3.0 CHEMISTRY METHODS

3.1 Analysis

Total residual chlorine was measured using the DPD (N,N-diethyl-p-phenylenediamine) colourometric method calibrated against dilutions of standard solutions of TRC prepared by HACH. The method provides detection to 0.05 mg TRC/L.

Total ammonia nitrogen was measured using the Nesslerization spectrophotometric method which was also calibrated against dilutions of standard solutions prepared by HACH. The limit of senstivity was 1 mg/L for this analytical method.

Both analytical methods provided adequate sensitivity to measure potentially lethal levels of chlorine and ammonia, and also allowed immediate measurement of toxicants to efficiently determine whether toxicant removal or the dosing of reactive agent was required. The measured concentrations of chlorine and ammonia were not considered nor intended to be highly accurate, but were used as rapid indicator tests providing direction in the toxicity assessment program.

3.2 Toxicant Removal

Chlorine removal was accomplished by the stochiometric addition of sodium sulphite (2 mg Na_2SO_3 per mg total chlorine residual to provide a 15% overdose). Total chlorine residual was measured before and after sodium sulphide addition, to confirm that the residual was non-detectable.

Total ammonia removal was accomplished by filtration with the zeolite ion resin clinoptilolite.

The ammonia exchange capacity of the resin was determined in advance, sufficient resin to treat the volume of effluent required for testing was packed in a glass column, and the effluent was pumped through the column over eight hours. The treated effluent was analyzed to ensure that total ammonia was below 1 mg/L.

4.0 HISTORICAL DATA OF ACTIVATED SLUDGE STP EFFLUENT TOXICITY

The MOE (1986) conducted three rainbow trout toxicity tests on the final effluent of the Waterloo STP coincident with some of the tests carried out during this study. As was the case with all 31 samples tested by BEAK, the effluent was not acutely lethal to rainbow trout or Daphnia magna. Earlier work by Metikosh et al. (1980) also showed that the final effluent from Waterloo STP was not lethal to rainbow trout.

One of 17 non-chlorinated samples from the Galt STP was acutely lethal to Daphnia in the present study, while two of 17 chlorinated samples caused mortality. Metikosh et al. (1980) reported similar results using rainbow trout, with one in 15 samples from the Galt STP causing acute lethality.

Table 3.1 presents the results of toxicity tests conducted on the effluents of other activated sludge STPs in Ontario. It is evident that LC50s have been calculated for few of the STP effluents, making quantified comparisons difficult. It can be noted, however, that the majority of activated sludge effluent samples are not acutely lethal. The toxicity results of Galt, Waterloo and Welland STPs are typical of this, and show that effluent toxicity varies dramatically within samples from any one STP, as well as among different STPs.

The toxicity results of other Canadian STP effluents are presented in Table 3.2. Again, the toxicity range is wide. It is evident from the results of Tables 3.1 and 3.2 that the activated sludge process itself is not responsible for a particular degree of toxicity, but that individual characteristics of each plant (e.g., operating efficiency) are likely responsible. These will be discussed further in Section 4.0.

TABLE 1: COMPARISON OF TOXICITY RESULTS FROM ACTIVATED SLUDGE STPs IN ONTARIO

Facility	No. of Samples	Test Type	Effluent Type	No. of Lethal Samples*	LC50 Range (%)	Reference
Brampton Experimental	17	CF	Non-chlorinated	2	NC	1
	12	CF	Chlorinated	12	NC	
Brantford	15	S	Non-chlorinated	3	NC	2
Burlington (Skyway)	14	S	Non-chlorinated	0	NC	2
Elmira	7	S	Non-chlorinated	5	39-GT 100	3
Galt	15	S	Non-chlorinated	1	NC	2
	17	S	Non-chlorinated	1	84-GT 100	This Study
	17	S	Chlorinated	2	66-GT 100	This Study
Guelph	29	S	Non-chlorinated	12	NC	2
Hamilton	13	S	Non-chlorinated	2	NC	2
Hespeler	15	S	Non-chlorinated	7	NC	2
Ingersoll	3	S	Non-chlorinated	1	43-GT 100	3
	30	S	Non-chlorinated	0	NC	2
Lakeview	43	S	Non-chlorinated	4	NC	2
Orangeville	15	S	Non-chlorinated	2	NC	2
Preston	15	S	Non-chlorinated	4	NC	2
Stratford	14	S	Non-chlorinated	0	NC	2
Tillsonburg	15	S	Non-chlorinated	0	NC	2
Waterdown	15	S	Non-chlorinated	8	NC	2
Waterloo	3	S	Non-chlorinated	0	GT 100	4
	14	S	Non-chlorinated	0	GT 100	This Study
	18	S	Chlorinated	0	GT 100	This Study
Welland	14	S	Non-chlorinated	0	GT 100	This Study
	15	S	Chlorinated	4	8-GT 100	This Study

* No. of 100% effluent samples which killed 50% or more of test organisms (rainbow trout or Daphnia).

Test Type: CF - continuous-flow
S - static

LC50 Range: NC - LC50 not calculated
GT - greater than

References

1. Cairns and Conn (1979)
2. Metikosh et al. (1980)
3. MOE (1983)
4. MOE (1986)

TABLE 2: COMPARISON OF TOXICITY RESULTS FROM ACTIVATED SLUDGE STPs OUTSIDE OF ONTARIO

Facility	No. of Samples	LC50 Range (%)	Reference
Cache Creek, B.C.	8	52.5 to 87	Higgs (1977d)
Mission, B.C.	8	GT 100	Higgs (1977b)
Moosejaw, Sask.	1	50 to 75	Spink et al. (1977)
Penticton, B.C.	8	L 32 to 99	Higgs (1977c)
Prince George, B.C.	4	GT 100	Higgs (1977a)

5.0 CHEMICAL COMPONENTS OF STP EFFLUENTS CONTRIBUTING TO TOXICITY

Chlorine and ammonia levels have been the most frequently cited sources of toxicity in sewage treatment plant effluents. Fairly consistently, one or both of them has been measured in lethal effluents in sufficient quantity to implicate them as primary toxic agents. Occasionally, ammonia and chlorine cannot account for all the observed toxicity, and other contaminants must be present and contributing to toxicity (e.g., metals, organic compounds and anionic surfactants).

It is difficult, in a toxicity assessment of a complex mixture of chemicals, to determine the level at which the chemicals present make a significant contribution to the toxicity of the mixture. This issue has been addressed by several authors (Alabaster and Lloyd, 1982; Konemann, 1979, 1980), who evaluated the available evidence from the literature, suggested that lethality of a mixture could be predicted based on the number of contaminants present at levels over 0.1 or 0.2 of their "threshold LC50". The threshold LC50 is the concentration which produces no greater than 50% mortality in organisms exposed for an indefinite period of time. This concentration is usually similar to the 96-hour LC50 for fish and the 48-hour LC50 for small invertebrates (Sprague, 1973). Therefore, substances present at concentrations greater than 0.2 of their LC50 are considered to contribute additively to toxicity, and those present at less than 0.2 times their LC50 are expected to exhibit little or no additive contribution. This concept has been supported by other authors (Sprague, 1973; Bradley, 1986), and has been incorporated into this STP evaluation. By this approach, it is possible to focus on the contaminants most likely to contribute to lethality and avoid the confounding influence of other compounds present in low concentrations.

5.1 Ammonia

Ammonia has been the most frequently cited cause of effluent lethality in laboratory toxicity tests of non-chlorinated STP effluents. Un-ionized ammonia (NH_3) is the toxic form and concentrations of 0.1 to 2.0 mg NH_3/L are lethal to rainbow trout (Craig, 1985). *Daphnia* are slightly less sensitive, with LC50s of 2 to 3 mg NH_3/L (Craig, 1985; Gersich and Hopkins, 1986). The equilibrium between ionized and un-ionized species is affected by pH and temperature, according to the following equation (Emerson *et al.*, 1975):

$$\text{Fraction of Total Ammonia in Un-ionized Form} = \frac{1}{1 + 10^{(pKa-pH)}}$$

$$\text{where: } pKa = 0.09 + \frac{2{,}730}{273 + T} \quad \text{and } T = {}^{\circ}C$$

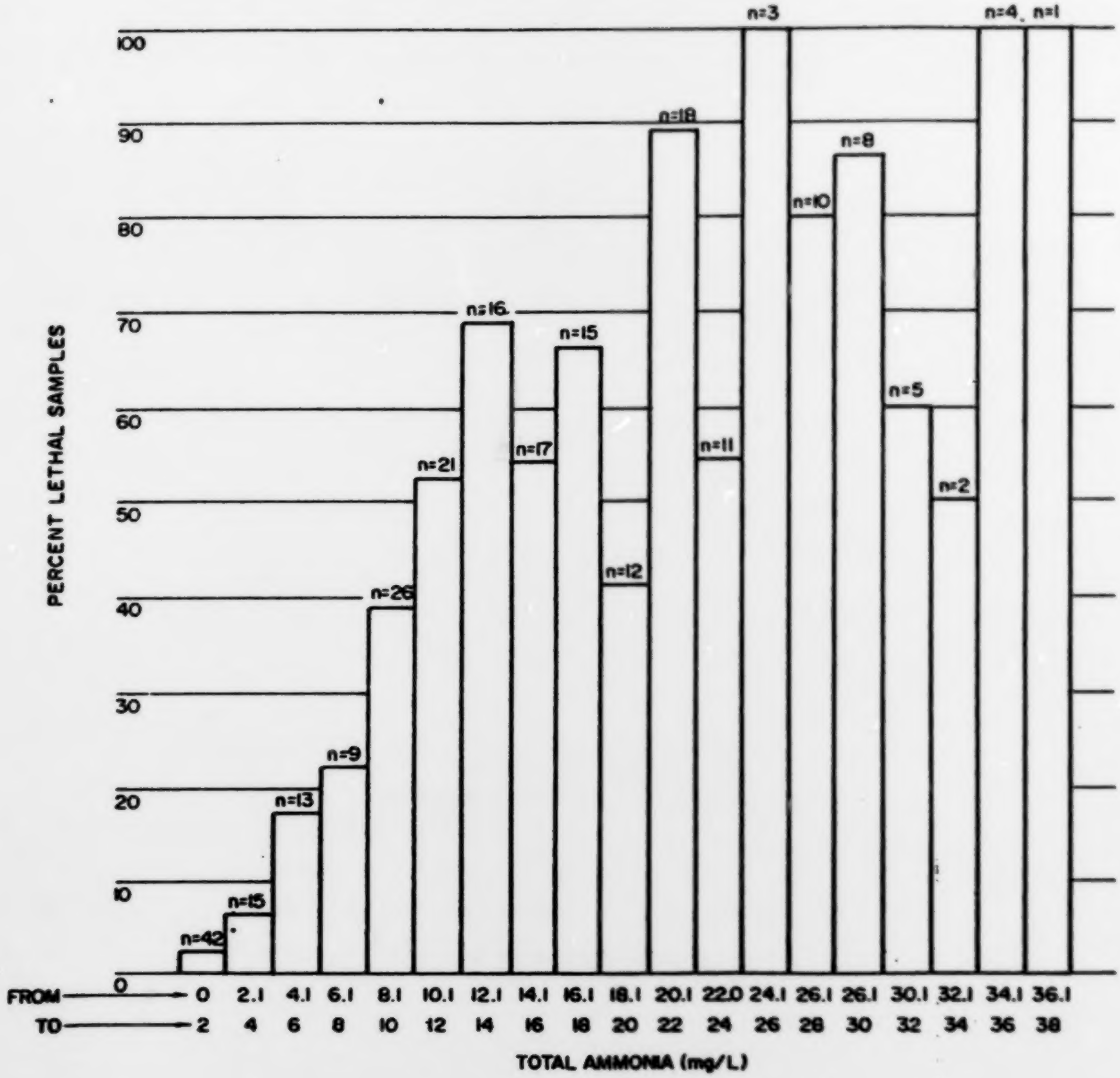
Un-ionized ammonia was present in Galt STP influent and effluent at levels sufficient to account for partial toxic contribution to rainbow trout and Daphnia. No concentration-dependent relationship to lethality was observed, however. Un-ionized ammonia was responsible for Waterloo influent lethality to rainbow trout and possibly contributed to Daphnia lethality. Effluent concentrations of ammonia were below acutely lethal levels at the Welland STP, but may have contributed to Daphnia lethality in chlorinated effluent. The concentrations of ammonia measured in the effluents from Waterloo were very low, and acute mortality did not occur among trout or Daphnia.

Since so few samples from Galt, Waterloo and Welland STPs proved to be lethal, it is difficult to establish a relationship between lethality and specific toxic components. If the data are combined with those from other Canadian STPs, it is possible to relate effluent lethality to ammonia. Figure 4.1 shows the relative frequency of lethal samples at each 2 mg/L increment of total ammonia. Above 10 mg/L, the frequency of lethal samples, with one exception, is greater than 50%. This suggests that elevated ammonia levels, particularly over 10 mg total NH_3/L are likely to cause or contribute to effluent lethality.

5.2 Chlorine

Chlorine, when added to water, tends to form hypochlorous acid and hypochlorite ion. These free chlorine forms react readily with ammonia and certain nitrogenous compounds to form combined chlorine, particularly chloramines. Total residual chlorine (TRC) measured in wastewater is the sum of free and combined forms (APHA, 1985). Both forms are highly toxic to aquatic organisms, although free chlorine may be slightly more potent (acute LC50's are usually in the range of 0.08 to 0.3 mg/L).

FIGURE 4.1 Total Ammonia-Nitrogen vs. Relative Frequency of Acutely Lethal Effluent Samples



Three of four lethal samples from Welland STP became non-lethal to Daphnia after dechlorination. The toxicity of the fourth sample was reduced from an LC50 of 8% to 25%. Clearly, residual chlorine contributed to effluent lethality.

There was a lack of correlation between lethality and TRC concentrations in the effluent samples from the three plants. One possible reason is the poor accuracy and precision of TRC measurement below 0.5 mg/L using the DPD method. In addition, free chlorine is rapidly dissipated from water, while chloramines tend to persist approximately ten times longer (Snoeyink and Markus, 1973, as cited in Johnson, 1976). Therefore, depending on the ammonia concentration in the effluent sample, toxicological effects due to TRC after sample handling and storage may not represent the true nature of the effluent.

There have been studies where TRC toxicity has been demonstrated below Canadian STP outfalls (Osborne et al., 1981; Flood et al., 1984). The studies of Tsai (1968, 1970, 1973) are frequently used as examples of the effect of TRC on receiving waters, but residual chlorine was not even measured in 1968 and 1970, and was measured by the inaccurate orthotolidine method (APHA, 1985) in 1973. Few experiments have thoroughly examined the potential role of other contaminants downstream from STP outfalls coincident with reliable TRC analysis (e.g., amperometric titration, APHA, 1985).

The importance of TRC toxicity remains ill-defined with respect to receiving water impact. It is likely that chlorination of an effluent with elevated ammonia nitrogen leads to increased receiving water impact due to the formation of more persistent chloramines. Ammonia itself, however, may also contribute to toxicity in such a case. The amount of dilution available will also determine the effect of TRC in the receiving water. In addition, the level of TRC maintained in the effluent and the degree of accuracy with which it is measured would also help determine the impact of the effluent on the receiving environment.

5.3 Metals

Metals have been reported as possible contributors to STP effluent toxicity (Huggett, 1974; Martens and Servizi, 1976; Higgs, 1977c; Ward and DeGraeve, 1978). The metal concentrations measured in the final effluents from the Galt, Waterloo and Welland treatment plants are presented in Tables 4.1 to 4.3, respectively. Representative

TABLE 4.1: CONCENTRATIONS OF INORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	pH		Total NH_3-N		Cd		Cr		Cu		Ni		Pb		Zn	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
30.09.86[c]	8.58	7.32			1	1	53	19	100	21	27	28	10	5	146	46
01.10.86[d]	7.50	7.20			4	2	168	24	129	30	46	22	15	5	413	63
02.10.86	8.35	7.40			4	2	69	27	130	47	27	105	50	5	181	57
03.10.86	7.65	7.55			3	2	94	44	161	65	51	85	15	5	477	60
04.10.86	7.55	7.35			4	2	34	26	133	37	20	29	5	5	165	55
05.10.86[c]	7.70	7.50			1	1	22	23	111	34	16	20	10	5	145	43
06.10.86[d]	7.90	7.50			7	2	70	28	171	52	60	19	25	5	376	75
07.10.86	7.75	7.60		14.4	2	2	63	30	115	45	117	27	5	5	271	86
08.10.86[a,b]					6	4	88	32	129	66	30	73	20	5	203	68
Low Loading																
01.10.86	7.60	7.20		14.6	2	2	23	19	49	48	18	29	5	5	81	51
02.10.86	7.50	7.50	5.8	11.3	3	1	35	25	55	37	29	162	10	5	92	60
03.10.86	8.30	7.60		11.3	3	3	33	39	66	69	19	123	5	5	78	95
04.10.86	7.80	7.60		10.9	2	2	25	32	63	44	16	36	5	5	71	80
05.10.86	7.55	7.60		12.6	2	2	22	26	46	32	17	25	5	5	83	75
06.10.86[b]	7.40	7.50		15.0	2	2	34	27	48	38	24	28	10	10	72	84
07.10.86	7.50	7.70		12.9	2	11	82		149	32	41	27	15	5	223	189
08.10.86	7.50	7.52		12.2	20	5	252	35	112	80	41	100	5	5	119	132

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[a] Non-chlorinated and [b] chlorinated effluent sample toxic to Daphnia magna.

[c] Influent sample lethal to Daphnia magna.

d Influent sample lethal to Salmo gairdneri.

TABLE 4.2: CONCENTRATIONS OF INORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFFLUENTS (ug/L)*

Date	pH	P		P(filt.)		Cd		Cr		Cu		Ni		Pb		Zn	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																	
02.07.86	7.2	7,070	820	3,900	770	4	4	74	20	118	13	24	17	105	5	339	55
04.07.86	7.2	10,500	850	3,690	310	5	4	58	25	141	7	26	20	30	5	163	71
05.07.86	7.5	6,970	990	4,000	380	6	5	33	26	105	9	22	25	5	5	138	85
06.07.86	7.4	6,510	1,070	3,380	500	4	5	29	21	93	13	20	22	10	5	88	43
08.07.86	8.0	7,210	1,930	3,850	1,380	6	6	53	35	110	17	41	41	15	5	156	83
09.07.86	7.9	6,930	750	3,840	230	4	4	58	19	149	14	26	23	35	5	153	87
10.07.86	7.5	7,290	710	4,000	190	4	4	43	27	156	12	23	23	30	5	227	67
Low Loading																	
03.07.86	7.0	2,630	930	1,080	540	3	4	37	29	77	10	20	23	10	10	81	109
04.07.86	7.0	7,800	800	2,000	500	3	5	65	64	50	13	19	25	5	5	110	111
05.07.86	7.5	3,390	1,100	1,850	500	5	4	32	22	55	14	24	27	10	5	69	104
06.07.86	7.3	3,210	1,000	1,540	540	6	6	29	21	46	13	21	23	5	5	51	50
09.07.86	7.4	3,030	1,030	620	380	6	5	38	29	115	15	25	27	70	70	143	77
10.07.86	7.5	3,140	830	620	270	4	3	29	24	82	11	19	24	5	5	112	79

* No samples were acutely lethal to Daphnia magna nor Salmo gairdneri.

TABLE 4.3: CONCENTRATIONS OF INORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENTS

Sample Date	P (mg/L)		P (filt.) (mg/L)		Cd (ug/L)		Cr (ug/L)		Cu (ug/L)		Ni (ug/L)		Pb (ug/L)		Zn (ug/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Load																
19.08.86	2.49	0.92	1.33	0.47	3	3	11	10	19	5	14	17	5	5	37	25
20.08.86[c]	3.66	0.94	2.00	0.53	1	1	9	8	22	7	7	11	5	5	66	28
22.08.86[b]	2.09	0.80	1.20	0.40	5	4	20	17	17	11	16	18	5	5	42	20
23.08.86[b]	2.85	0.91	2.13	0.57	4	3	13	10	19	4	14	16	5	5	43	20
24.08.86[c,d]	3.51	0.85	2.00	0.55	3	2	14	8	35	4	15	12	5	5	52	17
27.08.86[b]	2.65	0.56	1.47	0.33	2	3	12	8	26	4	14	15	5	5	58	14
Low Load																
20.08.86[c]	3.44	0.87	2.13	0.53	3	2	13	6	22	3	12	12	5	5	29	36
21.08.86	3.45	0.92	1.87	0.67	3	1	13	8	17	7	14	9	5	5	39	23
22.08.86	2.92	0.86	1.73	0.53	3	3	23	9	19	6	20	13	5	5	36	25
24.08.86[b,c]	5.74	0.81	2.27	0.53	3	2	21	8	93	6	23	11	5	5	185	22
27.08.86	1.74	0.69	0.93	0.37	2	2	12	6	18	4	12	11	10	5	65	14

[a] Non-chlorinated and [b] chlorinated sample toxic to *Daphnia magna*.

[c] Influent sample toxic to *Salmo gairdneri*.

[d] Influent sample toxic to *Daphnia magna*.

rainbow trout and invertebrate 96-hour LC50 values for metals were taken from the literature and appear in Table 4.4. The latter table was used to determine whether concentrations measured at the three STPs may have contributed to observed lethality. Sublethal toxicity values are also presented for comparison.

It is evident from Table 4.4 that a wide range of toxic concentrations have been evaluated for fish and invertebrates. Where a range of LC50's has been reported, the lowest value for each species was used in the evaluation of toxic contribution. As discussed earlier, this was accomplished by comparing measured contaminant concentrations with 0.2 times the LC50 values for trout and Daphnia. Cadmium was, therefore, an unlikely source of toxicity in effluents from the three STPs, since it never exceeded 20 ug/L for Daphnia or 27 ug/L in rainbow trout tests. Similarly, chromium, nickel, lead and zinc concentrations in Galt, Waterloo and Welland effluents were all below 0.2 of the lowest reported LC50 values, and no lethal samples corresponded with peak concentrations of any of these metals.

Copper concentrations met or exceeded 0.2 of the LC50 in most influents and in some effluents from the Galt and Waterloo STPs. Although all 17 effluent samples from Galt exceeded 0.2 of the LC50 (12 ug/L assuming an LC50 of 60 ug/L), only three samples were lethal, and these were not associated with the highest copper concentrations. In the effluent from Waterloo, nine of 13 samples measured 12 ug Cu/L or more, and no lethality was observed in any samples. Therefore, the contribution of copper to effluent toxicity is unclear.

Copper was found in lethal concentrations at three STPs by Martens and Servizi (1976), but no significant concentration-lethality relationship was identified. Copper was the only metal of six measured by the EPA (1977) to reach potentially toxic levels in an STP effluent in Memphis, Tennessee. The effluent was lethal, but observed mortality was not related to any particular effluent characteristics by the authors. Tsai and McKee (1978) reported additive or synergistic effects of copper, LAS (linear alkylbenzene sulphonate) and chloramines, but statistical analyses were not performed to determine significant differences between LC50's of the various mixture ratios, nor were the contributions of each chemical quantified.

TABLE 4.4: DOCUMENTED TOXIC CONCENTRATIONS (ug/L) OF VARIOUS METALS AND ORGANICS TO FISH AND INVERTEBRATES

	Rainbow Trout LC50's	Daphnia LC50's
Inorganics		
Cd[1,2]	100-2,000	65
Cr[3]	3,400-65,500	435-58,700
Cu[1]	20-102	80-85
Ni[4]	32,000	510-1,120
Pb[1,5]	1,000-6,500	450
Zn[1,2]	135-7,210	100-280
Phosphorus		
Organics		
Benzene[7]	9,200	
Chloroform[12]	23,900-36,500	
1,4-Dichlorobenzene[8]	1,120-1,200	11,000
Ethylbenzene[7]	14,000	
Phenols		
Tetrachloroethylene[11,13]	13,400-20,300	17,700
Toluene[7,9]	24,000	313
1,1,1-Trichloroethane[13]	42,300-52,900	
Trichloroethylene[10,13]	42,300-52,900	85,200
Xylene[7]	8,200-13,500	

[1] Environment Canada (1979-1980)

[2] IJC (1977)

[3] Eisler (1986)

[4] IJC (1978)

[5] IJC (1980)

[6] Tentative PWQO values under consideration by MOE.

[7] Mayer and Ellersieck (1986)

[8] MOE (1984a)

[9] EPA (1980b)

[10] EPA (1978a)

[11] EPA (1978b)

[12] EPA (1980a)

[13] Geiger et al. (1985). Data are for fathead minnows. The interspecies comparison between fatheads and rainbows developed by Thurston et al. (1985) indicates that the rainbow trout LC50's would be as much as two times higher. Therefore, the values cited here are conservative estimates.

Zinc concentrations were also measured at potentially toxic levels in some influents and effluents from Galt, Waterloo and Welland. They were not, however, consistently associated with lethality.

Metals may make a contribution to STP effluent lethality, but they are not expected to be primary causative agents. Clearly, further research is required to clarify this issue.

5.4 Organic Compounds

The levels of organic compounds measured in the effluents from Galt, Waterloo and Welland STPs are presented in Tables 4.5 to 4.7, respectively. These values fall well short of 0.2 times the representative LC50 values shown earlier in Table 8. Therefore, none of the organics analyzed were likely significant contributors to effluent lethality. One possible exception was xylene which was measured in an influent sample from Galt (30.09.86, high load). That sample was acutely lethal to Daphnia. Other studies have also reported low concentrations of organic compounds in STP effluents (Kopperman, 1976; EPA, 1977; Melcer, 1986).

5.5 Surfactants

While surfactant concentrations were not measured in the three-plant study, their involvement in STP effluent toxicity has frequently been suggested. Surfactants enter sewage treatment plants in domestic and industrial wastewaters. Anionic surfactants are the most common type of surfactant, and usually arise from the use of detergents. They may vary in molecular chain length, and take on a branched or linear structure (Abel, 1974). The methylene blue active substances (MBAS) method is commonly used to estimate the anionic surfactant content of water and wastewaters (APHA, 1985). Linear alkylbenzene sulfonates are the most widely used anionic surfactants, and are used to standardize the MBAS method.

The lethality of anionic surfactants increases as the number of carbon atoms increases and as the position of the phenyl moeity is located in a more terminal than central position in the chain (Kimberle and Swisher, 1977). The toxicity of anionic surfactants can range over an order of magnitude, depending on the molecular structure and organism tested. For example, the 96-hour LC50 to bluegill sunfish was 0.6 mg/L for a

TABLE 4.5: CONCENTRATIONS OF ORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	Phenolics (4-AAP)	Chloroform		1,1,1-Trichloroethane		Benzene		Trichloro-ethylene		Toluene		Tetrachloro-ethylene		Ethyl Benzene		p & m-Xylene		1,4-Dichloro-benzene	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Load																			
30.09.86[c]	1.0	2.01	0.50	3.56	2.30	0.97	0.25	3.59	1.00	0.25	0.25	12.23	8.75	218.98	0.56	1,146.77	1.38	4.51	2.43
01.10.86[d]	5.0	2.60	1.00	4.99	1.59	0.87	0.25	4.98	1.00	4.21	0.25	25.62	6.02	1.36	0.25	6.51	0.25	6.28	1.16
02.10.86	7.8	2.27	1.00	5.67	1.54	1.06	0.25	4.44	1.00	3.76	0.25	22.37	5.07	50.86	0.25	302.63	0.25	5.46	1.14
03.10.86	3.4	1.95	1.00	6.58	2.17	0.75	0.25	4.79	0.50	3.35	0.25	5.39	3.17	2.62	0.25	12.84	0.25	5.96	1.07
04.10.86	2.4	3.14	1.00	6.01	3.29	0.90	0.25	5.20	1.00	2.79	0.25	6.16	2.18	0.66	0.25	3.04	0.25	4.96	1.00
05.10.86[c]	3.2	1.21	0.50	6.03	1.00	0.91	0.25	5.37	0.50	3.56	0.25	1.14	1.00	0.58	0.25	2.75	0.25	5.35	1.00
06.10.86[d]	5.2	1.51	0.50	5.70	1.44	0.56	0.25	4.39	1.00	4.62	0.25	8.98	0.50	0.25	0.25	8.98	0.25	4.22	1.05
07.10.86	4.6	1.47	0.50	4.64	1.41	0.50	0.25	4.99	1.00	2.60	0.25	8.26	0.50	1.17	0.25	5.57	0.25	5.53	1.35
08.10.86[a,b]	8.0	48.14	0.50	5.13	1.54	0.50	0.25	5.49	1.00	5.33	0.25	3.17	1.00	0.97	0.25	4.98	0.68	5.05	1.18
Low Load																			
01.10.86	2.8	0.50	1.00	3.70	2.38	0.61	0.253	3.42	1.00	1.84	0.25	5.15	35.03	0.59	0.50	3.19	1.68	2.23	1.77
02.10.86	1.0	1.16	1,00	5.56	2.25	1.00	0.253	5.23	1.00	3.48	0.25	4.33	17.63	0.82	0.25	5.11	0.25	3.33	1.36
03.10.86	6.8	0.50	1.00	3.93	2.48	0.53	0.253	3.04	0.50	1.48	0.25	1.62	13.13	0.50	0.25	1.81	0.25	2.03	1.27
04.10.86	6.8	1.02	1.00	5.74	2.64	1.04	0.25	5.09	1.00	3.16	0.25	3.30	5.56	0.92	0.50	4.84	0.50	3.42	1.20
05.10.86	2.4	1.00	1.00	5.94	1.90	0.88	0.25	5.18	1.00	5.32	0.25	2.42	1.08	09.50	0.25	2.38	0.25	3.60	1.33
06.10.86[b]	3.0	4.38	0.50	5.56	1.90	0.80	0.25	5.07	1.00	24.87	0.25	19.36	1.00	1.49	0.25	7.39	0.25	5.10	1.26
07.10.86	6.8	2.47	0.50	5.94	1.56	0.56	0.25	5.21	1.09	2.40	0.25	2.21	1.00	0.84	0.25	4.73	1.20	3.29	1.57
08.10.86	4.0	1.00	0.50	1.54	1.92	0.25	0.25	1.03	1.00	0.50	0.25	0.50	2.21	0.25	0.50	20.50	4.33	1.00	1.33

[a] Non-chlorinated and [b] chlorinated sample caused acute lethality to *Daphnia magna*

[c] Influent sample lethal to *Daphnia magna*

[d] Influent sample lethal to *Salmo gairdneri*

TABLE 4.6: CONCENTRATIONS OF ORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFFLUENT (ug/L)*

Sample Date	Phenolics		Benzene		Chloroform		1,4-Dichlorobenzene		1,1,1-Trichloroethane		Trichloroethylene		Toluene		P&M-Xylene	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
02.07.86		3.7	1.24	0.50	1.03	1.96	5.92	0.50	0.50	1.00	1.68	0.50	4.03	0.25	118.86	0.25
04.07.86	14.3	1.1	0.68	0.25	1.98	0.50	0.50	0.50	1.00	0.50	1.83	0.50	2.73	0.50	302.4	0.25
05.07.86	35.9	6.9	1.33	0.50	9.49	1.84	8.73	1.00	0.50	1.06	1.00	0.50	2.86	0.50	7.74	0.50
06.07.86		1.3	0.61	0.25	0.50	0.50	6.60	1.00	0.50	0.50	1.00	0.50	1.35	0.25	2.77	0.25
08.07.86	22.8	4.0	0.59	0.25	5.75	1.63	1.82	0.50	2.98	0.50	2.89	0.50	4.44	1.03	17.14	0.50
09.07.86	34.4	1.5	0.80	0.25	5.41	0.50	0.50	0.50	1.48	1.04	1.60	0.50	2.76	0.25	14.23	0.25
10.07.86		2.2	1.32	0.25	2.21	1.80	0.50	0.50	1.00	1.70	1.35	0.50	3.41	0.25	4.76	0.25
Low Loading																
03.07.86	15.0	3.7	1.23	0.25	0.50	0.50	1.13	1.00	0.50	1.04	0.50	0.50	6.69	0.50	7.23	0.50
04.07.86	7.4	2.8	0.50	0.25	1.98	0.50	0.50	1.00	2.39	1.28	0.50	0.50	1.06	0.25	5.06	0.25
05.07.86	1.0	3.3	1.06	0.25	2.48	0.50	1.00	1.00	3.20	0.50	0.50	0.50	5.91	0.25	3.26	0.50
06.07.86	3.3	1.7	1.15	0.25	1.41	0.50	4.67	0.50	1.14	0.50	1.00	0.50	1.37	0.25	2.72	0.50
09.07.86	8.7	1.2	5.53	0.25	5.44	2.64	0.50	0.50	2.16	0.50	8.04	0.50	5.07	0.25	12.23	1.00
10.07.86	34.0	6.2	1.72	0.25	4.19	0.50	0.50	1.00	2.56	0.50	0.50	0.50	9.20	0.25	3.99	2.14

* No samples were acutely lethal to Daphnia magna nor Salmo gairdneri.

TABLE 4.7: CONCENTRATIONS OF ORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	Phenolics	Chloroform		1,4-Dichlorobenzene		Trichloroethylene		Toluene		P&M-Xylene	
		In	Out	In	Out	In	Out	In	Out	In	Out
High Load											
19.08.86	3.4	6.67	1.00	1.93	1.00	1.00	0.50	0.50	0.25	0.25	0.25
20.08.86[c]	5.0	4.19	1.00	2.29	0.50	1.00	0.50	1.17	0.25	4.32	0.67
22.08.86[b]	3.4	3.33	1.00	2.56	1.00	0.50	0.50	0.25	0.25	0.25	0.25
23.08.86[b]	1.0	3.73	1.01	2.04	1.00	0.50	0.50	0.50	0.25	0.25	0.25
24.08.86[c,d]	2.4	5.73	1.14	2.32	1.00	0.50	0.50	0.95	0.25	0.50	0.25
27.08.86[b]	1.0	0.50	2.19	2.19	1.00	0.50	0.50	0.50	0.25	0.25	0.25
Low Load											
20.08.86[c]	5.0	2.75	1.00	1.58	1.00	0.50	0.50	0.63	0.25	0.25	0.25
21.08.86	2.4	4.71	1.00	1.87	0.50	1.00	0.50	1.54	0.25	0.25	0.25
22.08.86	8.8	3.40	1.00	2.30	2.10	1.00	0.50	0.63	0.25	0.25	0.25
24.08.86[b,c]	1.6	3.56	1.00	2.64	1.00	1.00	0.50	1.58	0.25	0.25	0.25
27.08.86	2.4	3.10	0.50	2.14	1.00	0.50	0.50	0.91	0.66	0.76	0.25

[a] Non-chlorinated and [b] chlorinated sample toxic to *Daphnia magna*.

[c] Influent sample toxic to *Salmo gairdneri*.

[d] Influent sample toxic to *Daphnia magna*.

linear (14-carbon chain) surfactant (Swisher et al., 1964 in Abel, 1974), compared to 17 mg/L for a branched surfactant (Cairns and Sheier, 1962 in Abel, 1974). Kimberle and Swisher (1977) measured LAS LC50's of 0.5 to 50 mg/L to Daphnia and fathead minnows. Since the MBAS method measures all anionic surfactant forms present, correlations of surfactant concentrations to effluent lethality are impossible.

In a number of sewage plant effluent toxicity studies in British Columbia (Higgs, 1977), surfactants were considered contributary components of effluent lethality on the strength of MBAS analyses. A study by Esvelt et al. (1973) demonstrated that treatment of sewage effluent by ionic exchange resin or charcoal filtration reduced acute lethality. In that study, it appeared that reductions in surfactant concentrations decreased toxicity, but the authors did not attempt to identify what other toxicants may have been removed by activated carbon. It was concluded that, on an equivalent mass basis, surfactants contributed almost six times more to the effluent toxicity than total ammonia. However, they also acknowledged that 74% of the lethality was unaccounted for, and metals represented an obvious toxicant source that was not included in the relationship developed.

Surfactants may be reduced to non-toxic concentrations in most secondary STPs (Metikosh et al., 1980). It also seems unlikely that the more toxic long-chain surfactants would persist through the microbial action of secondary treatment. Assessment of surfactant contributions to effluent lethality may be elucidated by tests where alternative potential toxicants are not present.

6.0 PROCESS CHARACTERISTICS CONTRIBUTING TO EFFLUENT TOXICITY

A review of the BOD_5 removal efficiencies of Ontario STPs (BEAK and Canviro, in progress) indicated that effluents were more frequently toxic when total ammonia-N concentrations exceeded 10 mg/L. This was often the case during winter operation, with high total ammonia levels apparently resulting from reduced nitrification at lower wastewater temperatures.

The food-to-microorganism ratio (F/M) is a process operating parameter describing the organic loading treated by the biological section of a treatment plant. Low food-to-microorganism ratios (e.g., 0.05 to 0.15 day^{-1}) are typical of extended aeration plants, while conventional activated sludge plants maintain an F/M ratio between 0.2 and 0.4 day^{-1}. At low F/M ratios, populations of nitrifying bacteria may become well established in aeration tanks, resulting in lower total ammonia-N concentrations in effluents.

The relative industrial flow contribution appeared to have little effect on the acute lethality of Ontario secondary treatment plants when the total ammonia-N concentration exceeded 10 mg/L (BEAK and Canviro, in progress). When the total ammonia-N in the effluent was less than 10 mg/L, however, industrial contributions may have had some impact on effluent toxicity. In this latter grouping, lethality was only observed when the industrial input was major, in five of 28 effluents tested. It is possible that some unidentified contaminants resulting from industrial activities were responsible for the toxic responses.

Chlorination is the most widely used disinfection procedure of Ontario sewage treatment effluents. It occurs just prior to discharge, and can cause a near-field zone of lethality in receiving waters. Chlorination of ammonia-rich effluent results in the formation of chloramines which are more persistent than free chlorine, and may result in a more persistent far-field effect downstream of the discharge. The chlorine-ammonia interaction might be reduced by accurate residual monitoring through amperometric detection, coupled with a continuous feedback dosing system.

7.0 APPLICATION OF TOXICITY TEST RESULTS TO REGULATORY PROGRAMS

Toxicity estimates developed by comparison of measured contaminant levels with documented lethal concentrations are inadequate to ensure protection of receiving water biota. Toxicological data are unavailable for the thousands of toxic compounds that are regularly discharged into surface waters. Furthermore, many discharged compounds will not be detected by available analytical methods. Thirdly, chemical concentration data do not take into account possible interactions among pollutants and the cumulative toxic effect on aquatic biota. The U.S. National Pollutant Discharge Elimination System (NPDES), for example, has shown that assessment and control of the effects of toxic discharges on aquatic communities is often incomplete without the use of living organism toxicity tests (Wall and Hamner, 1987).

Toxicity tests more accurately reflect potential biological effects in receiving environments. The U.S. EPA has demonstrated, through laboratory and field studies, that biological testing is a scientifically valid approach to control toxicants in wastewater discharges (Wall and Hamner, 1987). The Ontario Ministry of the Environment has recently announed their decision to implement regular biological tests in the "Effluent Monitoring Regulation for the Petroleum Refining Sector" as part of the Municipal Industrial Strategy for Abatement (MISA) program. It is intended that regulations demanding such tests will eventually be applied to all major effluent discharges.

The means of incorporating toxicity tests in effluent quality regulation has yet to be finalized. Comparison of toxicity test results with compliance of PWQO's in the receiving environment will identify which provides the most stringent protection. The designated receiving water use requirements will then determine which level of protection is the most appropriate. For example, if the receiving water supplies drinking water, then the most appropriate regulatory device is the drinking water quality objective. However, if aquatic habitat protection is required, regulation using toxicity test data would be most appropriate.

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APPENDIX III

RAW DATA

FILENAME: WATCONC.WK1

WATERLOO WPCP : ANALYTICAL DATA

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	UNITS : mg/L										UNITS : ug/L																UNITS : ug/L	
				BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT P		Pb		Zn		PHENOL	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
6243	JUL 2	1200	50400			33.2	11.9	34.0		20.0	1.9	350	5	4	4	74	20	110	13	24	17	7070	820	3900	770	105	5	339	55		3.7
6245	JUL 2	1400	47400			37.9	11.7					300	7	4	2	95	23	206	11	28	19	7300	900	3700	540	40	5	214	55	10.0	3.0
6247	JUL 2	1600	40000			70.2	11.4	41.2			2.3	200	7	4	2	208	27	200	15	31	22	6830	1030	4610	420	50	5	200	80		1.4
6249	JUL 2	1800	34800	118	6	30.6	12.5					170	6	4	4	75	26	171	14	31	19	5350	990	2920	460	30	5	344	86	10.0	1.8
6251	JUL 2	2000	45000			20.4	9.9	27.4			2.1	170	6	3	3	53	25	131	14	50	21	6290	930	5050	500	15	5	221	87		7.7
6253	JUL 2	2200	39000			52.9	12.0					330	10	4	3	34	32	166	15	29	23	6470	990	2620	540	25	5	223	106	19.2	1.5
6255	JUL 2	2400	36000			43.2	11.7	30.6	2.5		1.5	150	5	3	4	45	20	129	7	22	20	6820	1010	5300	620	15	5	374	133	25.3	4.5
6257	JUL 3	0200	30600			20.5	15.4					100	6	3	3	42	27	93	15	21	25	5030	980	1540	500	25	10	230	119		
6259	JUL 3	0400	24600		6	25.2	11.0	64.1			1.0	100	5	3	4	37	29	77	10	20	23	2630	930	1000	540	10	10	81	109	15.0	3.7
6261	JUL 3	0600	27000			23.4	10.3					70	6	3	3	45	29	88	8	21	22	3050	1040	1050	620	5	5	85	96	16.0	2.7
6263	JUL 3	0800	31200			50.1	11.2	35.3			1.0	170	5	3	4	44	30	91	10	19	80	5360	1100	3700	380	5	5	83	80	43.3	4.7
6265	JUL 3	1000	45600			40.9	13.6					100	4	4	3	51	34	201	8	23	21	7230	970	3700	420	35	5	433	152	32.9	
6267	JUL 3	1200	45600			40.9	10.6	33.0		17.0	1.1	190	5	3	3	82	60	255	9	31	25	7000	980	3230	310	65	5	321	90	14.4	2.0
6269	JUL 3	1400	47400			49.4	11.2					190	8	3	3	123	62	195	9	28	25	6190	950	3000	300	50	5	249	82		3.6
6271	JUL 3	1600	40000			73.7	11.2	27.0			2.0	200	7	4	4	110	64	213	14	35	23	5850	970	2770	270	35	5	247	90	27.4	1.0
6273	JUL 3	1800	39600			83.4	11.4					200	7	4	4	126	55	161	13	39	25	6800	940	1080	350	35	5	259	94	20.9	5.1
6275	JUL 3	2000	37800			113.5	11.3	31.0			2.0	220	4	5	4	60	50	112	9	20	22	6230	890	4920	460	15	5	100	96	20.0	1.7
6277	JUL 3	2200	43000			30.8	11.0					170	9	4	3	86	54	102	13	25	23	6050	940	2460	300	10	10	166	110	18.9	1.9
6279	JUL 3	2400	34000			26.9	11.4	29.0			1.8	100	7	3	4	59	56	94	11	18	23	5610	870	3540	350	10	7	122	100	45.0	2.9
6281	JUL 4	0200	31000			31.7	11.4					110	6	3	4	75	69	73	11	21	30	4540	850	3000	310	10	5	80	130	15.3	1.6
6283	JUL 4	0400	23400			90.5	12.2	18.8		13.0	1.4	70	6	3	5	65	64	50	13	19	25	7800	800	2000	500	5	5	110	111	7.4	2.0
6285	JUL 4	0600	24600			21.6	11.2					80	7	5	4	69	72	49	16	21	29	2430	840	920	350	5	5	100	159	11.1	7.9
6287	JUL 4	0800	31200			43.4	11.5	37.0				100	5	5	5	70	52	91	7	25	23	7450	600	3000	380	15	5	198	79	25.5	1.4
6289	JUL 4	1000	43200			91.0	11.1					200	6	5	4	50	25	141	7	26	20	10500	850	3690	310	30	5	153	71	14.3	1.1
6291	JUL 4	1200	53400	194	6	62.1	11.4	34.5	2.9	17.0	1.2	160	6	5	1	73	30	161	4	36	25	6410	300	2770	350	30	5	201	70	44.3	
6293	JUL 4	1400	43000			55.4	11.7					130	8	5	4	60	26	125	8	25	23	6400	960	3080	380	15	5	183	114	25.6	6.5
6295	JUL 4	1600	39000			134.2	12.3	29.3			4.7	170	6	4	4	50	26	152	12	26	22	7020	1040	4460	500	20	5	160	85	34.1	5.6
6297	JUL 4	1800	40000			50.4	12.0					120	9	4	4	40	29	126	13	25	23	6110	1160	3230	400	15	5	150	81	39.2	5.3
6299	JUL 4	2000	43200			36.2	11.6	25.8			7.4	80	8	4	3	28	27	258	13	19	23	7630	1170	2300	540	15	20	145	84	16.0	3.1
6301	JUL 4	2200	35400			45.1	12.3					90	9	4	4	30	22	104	12	25	25	5840	1110	1230	540	10	5	149	85	20.4	
6303	JUL 4	2400	34800			27.0	11.0	28.5			7.1	60	7	5	5	27	28	113	10	22	26	5430	1100	770	650	10	5	156	112	5.0	3.9
6305	JUL 5	0200	27000			17.6	11.6					40	7	4	4	30	28	74	10	21	24	5450	1050	3690	460	8	5	80	90		
6307	JUL 5	0400	24800			20.6	11.6	17.6			5.7	30	7	5	4	32	22	55	14	24	27	3390	1100	1850	500	10	5	69	104	1.0	3.3
6309	JUL 5	0600	23400	28	2	17.8	11.3					40	7	5	6	47	30	40	14	25	25	2440	1000	1300	420	5	5	75	177		
6311	JUL 5	0800	22000			21.0	11.5	24.3			4.1	30	4	6	8	35	28	67	10	23	28	3710	890	2000	500	5	5	74	78		
6313	JUL 5	1000	33800			21.6	11.2					80	5	6	5	33	26	105	9	22	25	6970	990	4000	300	5	5	130	85	35.9	6.9
6315	JUL 5	1200	44400			32.3	12.2	36.0			2.8	120	4	5	6	32	22	106	11	29	25	7230	1050	3230	300	10	5	125	73	15.7	3.6
6317	JUL 5	1400	44400			28.6	11.6					90	4	5	6	29	26	108	9	21	23	6610	1020	3540	400	20	5	114	63	14.8	
6319	JUL 5	1600	38400			20.4	12.1	25.0			3.6	90	5	5	4	25	24	94	14	22	25	6210	1020	2770	420	5	5	153	65	20.0	3.7
6321	JUL 5	1800	35400			19.5	12.0					70	5	6	4	28	29	94	15	25	23	5020	1060	3300	620	10	10	130	104	18.5	1.1
6323	JUL 5	2000	34000			21.7	12.2	25.3	3.5		2.7	80	5	6	4	20	29	96	15	28	26	5800	1000	3000	460	15	10	209	129	9.2	7.9
6325	JUL 5	2200	35400			19.8	12.1					60	6	6	5	32	27	90	22	22	24	5970	1240	3300	500	20	15	179	127	12.3	
6327	JUL 5	2400	33000	94	6	19.1	11.8	26.2		19.1	1.5	60	4	6	5	30	27	85	15	23	19	5640	1060	3540	540	10	5	110	50	12.9	1.7
6329	JUL 6	0200	29400			16.4	11.6					40	5	5	5	27	23	65	16	19	18	4940	1000	2770	500	5	5	81	42	5.2	1.7
6331	JUL 6	0400	25000			14.3	11.3	10.6			1.0	40	5	6	8	20	21	48	13	21	23	3210	1000	1540	540	5	5	51	50	3.3	1.7
6333	JUL 6	0600	22000			11.0	10.8					20	6	8	5	38	23	44	16	23	20	2410	1210	1000	500	5	5	67	46	1.5	1.7
6335	JUL 6	0800	23400			13.1	11.1	10.4		14.4	1.3	30	3	5	5	29	21	51	14	18	22	2700	990	1230	460	5	5	46	38	2.6	1.6
6337	JUL 6	1000	31200			20.0	10.7					100	4	4	5	29	21	93	13	20	22	6510	1070	3300	500	10	5	88	43		1.3
6339	JUL 6	1200	40200			21.2	10.8				1.3	100	4	5	4	26	20	114	13	23	20	7100	1070	3230	500	15	5	109	38	10.6	2.4
6341	JUL 6	1400	42000			19.4	12.9					90	4	5	4	20	22	101	14	23	22	6080	1160	3300	620	10	5	100	33		

FILENAME: WATCONC.WK1

WATERLOO WPCP : ANALYTICAL DATA

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	UNITS : mg/L										UNITS : ug/L																UNITS : ug/L	
				BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		PHENOL	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
6343	JUL 6	1600	30600			29.9	12.3	22.4	2.4		1.6	60	8	5	4	20	26	84	21	19	30	5500	1520	3000	920	10	5	74	61	19.2	6.1
6345	JUL 6	1800	27600			27.4	13.3					70	10	5	5	19	22	87	18	19	22	5190	1620	2770	920	5	5	123	45	16.0	7.4
6347	JUL 6	2000	44300	97	6	32.1	12.8	25.2			2.5	60	3	5	5	22	20	96	6	18	21	5550	1070	3300	540	5	5	95	38	17.2	9.0
6349	JUL 6	2200	41400			38.5	14.3					80	3	5	6	33	37	108	8	23	21	6560	1040	3540	540	5	5	96	34	28.4	1.5
6351	JUL 6	2400	39700			28.5	12.9	20.7			2.5	60	3	5	6	22	22	89	13	26	22	5560	980	3380	690	5	5	74	43	20.9	1.9
6353	JUL 7	0200	32400			22.6	12.4					160	4	6	5	36	20	103	12	27	20	4200	1010	1380	650	100	5	92	33	18.5	3.8
6355	JUL 7	0400	26400			22.2	12.9	14.2	2.5		2.0	70	4	4	4	35	23	73	11	18	17	2860	1070	920	620	5	5	103	34	6.0	2.0
6357	JUL 7	0600	20800			24.9	11.6					40	4	3	4	33	19	56	9	19	18	2310	1100	920	620	5	5	64	33	12.9	2.6
6359	JUL 7	0800	30300			43.0	11.5	34.0			1.4	120	7	4	3	30	23	92	14	21	16	4590	1000	1230	1000	5	5	194	28	4.0	1.1
6361	JUL 7	1000	48000			43.7	10.2					100	10	5	3	70	27	194	21	41	18	7700	2190	2460	1460	32	5	192	35	30.9	
6363	JUL 7	1200	57600			60.7	11.5	28.8			1.4	120	7	4	4	80	20	230	19	38	18	7290	1890	4620	1230	5	5	228	47	29.4	1.0
6365	JUL 7	1400	56400	188	3	82.1	13.1					200	7	2	4	141	22	253	20	29	19	6950	1800	2920	1230	45	5	268	107	3.2	1.8
6367	JUL 7	1600	50000			88.1	13.0	27.6			2.4	1400	8	3	4	133	23	216	18	75	21	6600	2000	3080	1310	55	5	279	63	5.5	1.5
6369	JUL 7	1800	49200			55.8	14.0					130	7	4	3	113	38	150	21	41	31	5900	2100	3050	1380	35	5	151	75	17.5	2.7
6371	JUL 7	2000	48800			87.1	14.5	33.1		14.0	2.1	100	5	4	3	103	43	102	28	71	34	6140	2030	6150	1000	40	5	119	156	34.8	3.2
6373	JUL 7	2200	46800			105.0	15.3					70	5	4	4	50	25	117	20	27	25	6770	2460	4620	1460	5	20	152	89		
6375	JUL 7	2400	46200			50.0	14.7	26.2			3.2	80	4	4	4	27	100	97	21	23	82	5970	2000	3000	1500	5	15	89	87	16.0	1.0
6377	JUL 8	0200	37200			40.3	13.9					40	5	4	3	22	26	80	21	19	24	4140	2100	2460	1500	5	5	155	87		
6379	JUL 8	0400	29400			34.5	14.7	16.2			1.9	50	5	3	4	36	27	55	10	18	24	2460	2090	920	1690	5	5	132	81	63.1	1.2
6381	JUL 8	0600	31200			44.6	14.4					40	4	4	4	42	25	66	21	23	23	2280	1960	920	1460	5	5	81	84		4.5
6383	JUL 8	0800	36000			57.0	15.6	35.6			1.4	70	4	4	4	36	23	74	19	21	22	5500	2040	3000	1300	5	5	67	79	49.8	1.1
6385	JUL 8	1000	49800			54.7	14.8					100	5	6	6	53	35	118	17	41	41	7210	1930	3050	1380	15	5	156	83	22.0	4.0
6387	JUL 8	1200	52000			67.8	15.0	32.1			1.7	110	5	8	6	71	29	195	15	44	28	6730	1950	3230	1310	40	5	157	88	34.4	2.1
6389	JUL 8	1400	47400			70.9	15.1					130	6	6	6	56	30	204	21	44	36	6140	2070	2620	1420	28	5	151	96	22.3	3.1
6391	JUL 8	1600	47400	225	3	101.2	16.4	29.2			2.9	100	7	8	7	72	28	138	22	44	30	6570	2100	2460	1460	20	5	108	105	3.4	5.6
6393	JUL 8	1800	45600			79.9	15.3					120	7	8	4	48	26	146	19	51	26	6700	1700	2150	1000	30	5	121	89	24.4	4.0
6395	JUL 8	2000	49200			67.8	14.8	27.3		16.0	2.9	100	7	5	4	48	29	135	18	44	28	6540	1350	3230	730	15	5	122	88	30.7	6.5
6397	JUL 8	2200	45600			41.7	15.9					100	8	4	4	54	27	135	21	28	26	7240	1310	4000	690	15	5	101	88	21.8	1.2
6399	JUL 8	2400	45000			77.2	16.4	30.3			2.9	320	6	4	6	34	28	107	18	21	28	7460	1090	920	620	15	5	115	94	44.7	1.5
6401	JUL 9	0200	38400			88.8	16.3					100	8	5	4	29	25	89	16	23	27	5590	1050	2460	500	15	5	107	100	23.4	
6403	JUL 9	0400	30600			37.4	16.0	16.5			2.2	50	8	6	5	30	29	115	15	25	27	3030	1030	620	380	70	70	163	77	8.7	1.2
6405	JUL 9	0600	31800			50.5	14.9					70	7	6	4	42	21	48	15	24	28	2440	910	770	350	5	5	73	76	8.3	4.0
6407	JUL 9	0800	37200			20.8	15.9	32.0			1.6	70	8	5	4	33	25	104	16	23	26	5250	910	2150	270	8	5	90	81	45.2	3.4
6409	JUL 9	1000	51600	178	6	55.9	15.7					120	3	4	4	50	19	149	14	26	23	6930	750	3840	230	35	5	153	87	34.4	1.5
6411	JUL 9	1200	52000			81.2	18.0	38.8			1.6	290	4	5	4	73	23	272	18	33	23	7400	750	2150	230	50	5	295	83	20.3	7.4
6413	JUL 9	1400	51000			97.9	16.8					470	5	4	3	87	23	191	14	35	23	6030	820	770	270	40	5	318	75	38.3	
6415	JUL 9	1600	48000			111.0	16.2	30.0			2.7	120	5	5	4	98	19	315	15	39	23	6230	750	3000	230	80	5	196	95	33.1	5.5
6417	JUL 9	1800	40000			75.7	17.0					120	6	8	5	51	21	153	15	34	23	6940	710	3300	230	35	5	139	75	32.4	
6419	JUL 9	2000	53000			40.6	16.8			17.0	3.5	110	6	5	5	48	19	122	15	30	25	5890	670	3000	270	25	5	112	81	15.0	1.6
6421	JUL 9	2200	43000			33.4	18.0					150	6	5	4	44	16	115	15	29	22	6650	590	3540	150	10	5	91	60	27.8	5.2
6423	JUL 9	2400	46200			34.6	18.9				3.7	60	6	4	4	28	18	86	13	20	27	5110	580	2610	230	5	5	78	61	21.9	4.9
6425	JUL 10	0200	42000			72.3	15.9					90	6	4	4	25	24	29	15	17	25	2620	660	3000	270	5	5	44	112	21.2	4.5
6427	JUL 10	0400	30000			30.6	16.2	15.4			2.0	140	5	4	3	29	24	82	11	19	24	3140	830	620	270	5	5	112	79	34.0	6.2
6429	JUL 10	0600	31000			22.0	14.3					70	5	4	4	35	27	72	17	20	25	2290	710	620	230	5	5	103	70	18.6	4.2
6431	JUL 10	0800	37000	63	6	27.9	15.6	29.6		10.3	2.3	60	4	4	5	38	28	86	17	28	24	4160	650	2150	230	10	5	90	73	28.2	1.7
6433	JUL 10	1000	54000			58.9	14.0					150	5	4	4	43	27	156	12	23	23	7290	710	4000	190	30	5	227	67		2.2
6435	JUL 10	1200	56400			105.9	18.9				1.9	140	4	4	3	63	23	146	16	25	22	5010	680	3230	190	50	5	102	67	25.2	4.8
6437	JUL 10	1400	54000			84.6	15.2					120	4	4	4	77	23	150	14	31	21	5630	710	3000	150	30	35	243	71	25.6	
6439	JUL 10	1600	48000			89.1	16.0			15.6	2.8	90	4	4	3	78	22	175	14	28	23	5910	680	3540	310	5	5	136	67	27.7	3.9

FILENAME: WATCONC.WK1

WATERLOO WPCP : ANALYTICAL DATA

05/30/88

SAMPLE DATE TIME I.D.	FLOW (m^3/d)	UNITS : mg/L										UNITS : ug/L																UNITS : ug/L	
		BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		PHENOL	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Num Data Points	99	9	10	99	99	45	5	11	40	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	85	82
Average	39074	150.9	5.04	40.01	13.20	20.70	2.50	16.70	2.47	138.57	5.01	4.52	4.17	54.10	30.04	121.95	14.31	27.33	24.05	5646.87	1149.19	2777.50	614.04	20.41	8.74	152.89	81.93	21.69	3.34
Std. Deviation	9373	67.54	1.55	27.61	2.06	8.47	0.55	2.30	1.39	157.40	1.99	1.07	1.02	36.25	14.03	57.32	4.14	10.27	8.95	1646.70	454.77	1204.20	390.40	20.29	7.56	70.00	30.00	12.40	2.00
Minimum Value	22000	28.00	2.40	11.00	9.90	14.20	2.00	13.00	1.00	20.00	3.00	2.00	1.00	19.00	16.00	29.00	4.00	17.00	16.00	2200.00	300.00	620.00	150.00	5.00	5.00	44.00	20.00	1.00	1.00
Maximum Value	50000	275.0	8.00	134.20	18.00	84.10	3.50	20.00	7.40	1400.00	18.00	9.00	7.00	206.00	100.00	315.00	26.00	75.00	82.00	10500.00	2600.00	6150.00	1830.00	105.00	70.00	633.00	177.00	63.10	9.00

VOLATILE ORGANICS, WATERLOO WPCP
PROJECT 431

FILENAME : WATVOLA.WK1

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (M^3/D)	BENZENE		CHLOROFORM		1,4-DICHLOROBENZENE		1,1,1-TRICHLOROETHANE		TRICHLOROETHYLENE		TOLUENE		P&M - XYLENE		TETRACHLORO ETHYLENE		ETHYL BENZENE		O-XYLENE		1,2-DICHLORO BENZENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
6243	JUL 2	1200	50400	1.24	0.50	1.03	1.96	5.92	0.50	0.50	1.00	1.00	0.50	4.03	0.25	118.06	0.25	0.50	1.00	23.01	0.50	39.90	0.50	0.50	1.00
6245	JUL 2	1400	47400	0.88	0.25	3.25	1.60	1.00	0.50	1.46	0.50	1.25	0.50	0.80	0.25	1.50	0.25	1.00	1.00	0.50	0.50	0.01	0.50	0.50	1.00
6247	JUL 2	1600	48000	1.70	0.25	1.00	2.00	4.19	1.00	2.44	0.50	1.32	0.50	3.65	0.25	5.03	0.25	0.50	1.00	1.19	0.50	1.64	0.50	4.00	1.00
6249	JUL 2	1800	34000	1.21	0.25	1.35	0.50	3.90	1.00	0.50	0.50	0.50	0.50	4.33	0.25	3.40	0.25	1.00	1.00	0.90	0.50	1.40	0.50	0.50	1.00
6251	JUL 2	2000	45000	1.09	0.25	3.43	1.00	0.50	1.60	0.50	1.00	1.00	0.50	1.73	0.50	4.92	4.70	0.50	1.00	1.23	1.06	2.13	1.92	12.35	1.12
6253	JUL 2	2200	39000	1.17	0.25	2.23	1.00	3.08	1.72	1.33	0.50	0.50	0.50	2.60	0.50	4.34	2.15	1.00	1.00	0.25	0.50	3.55	0.50	1.00	1.00
6255	JUL 2	2400	38600	0.88	0.25	2.97	0.50	0.50	0.50	1.08	1.00	1.35	0.50	1.02	0.50	4.99	0.25	1.00	1.00	1.10	0.50	3.19	0.50	1.00	1.00
6257	JUL 3	0200	30000	1.42	0.50	2.50	2.02	12.02	1.00	0.50	0.50	11.28	1.71	17.02	0.50	50.06	0.50	4.07	1.00	14.43	0.50	12.29	0.25	1.00	1.00
6259	JUL 3	0400	24600	1.23	0.25	0.50	0.50	1.13	1.00	0.50	1.04	0.50	0.50	0.69	0.50	7.23	0.50	0.50	1.00	1.70	0.50	2.09	0.50	1.00	0.50
6261	JUL 3	0600	27000	1.30	0.25	0.84	1.22	1.00	0.50	1.00	1.04	1.00	0.50	1.40	0.25	4.17	0.25	1.00	1.00	1.05	0.50	0.25	0.50	0.50	1.00
6263	JUL 3	0800	31200	1.91	0.25	3.82	1.01	5.74	1.00	3.34	0.50	1.10	0.50	3.52	0.25	10.60	0.25	0.50	1.00	5.39	0.50	10.46	0.50	2.90	1.00
6265	JUL 3	1000	45600	1.33	0.25	1.12	0.50	1.25	1.00	4.33	1.92	1.10	0.50	4.28	0.25	26.50	0.25	3.04	1.00	5.53	0.50	0.30	0.50	1.00	1.00
6267	JUL 3	1200	45600	1.36	0.25	1.24	0.50	0.50	1.00	0.50	0.50	1.16	0.50	3.74	0.25	13.59	0.25	1.40	1.00	3.12	0.50	7.28	0.50	1.00	1.00
6269	JUL 3	1400	47400	5.42	0.25	0.50	0.50	0.50	1.00	1.00	0.50	1.90	0.50	7.60	0.25	9.02	0.25	0.50	1.00	2.29	0.50	5.66	0.50	1.00	1.00
6271	JUL 3	1600	40000	7.40	0.25	1.62	0.50	0.50	1.00	1.00	0.50	2.55	0.50	3.45	0.25	8.52	0.25	1.00	1.00	1.49	0.50	5.47	0.50	1.00	1.00
6273	JUL 3	1800	39600	1.20	0.25	2.05	0.50	2.90	1.00	3.11	0.50	1.00	0.50	4.21	0.25	15.09	0.25	0.50	1.00	3.70	0.50	2.10	0.50	1.00	0.50
6275	JUL 3	2000	37800	1.23	0.25	5.73	1.00	0.50	1.10	2.11	1.00	1.70	0.50	2.11	0.25	7.23	0.25	0.50	1.00	1.70	0.50	2.09	0.50	1.00	1.00
6277	JUL 3	2200	43000	0.98	0.25	2.08	1.00	3.56	1.26	1.36	0.50	0.50	0.50	1.74	0.25	3.14	0.50	0.50	1.00	0.25	0.50	1.92	0.25	1.36	0.50
6279	JUL 3	2400	34000	1.10	0.50	11.30	2.00	0.50	1.29	0.50	0.50	1.00	0.50	0.50	0.50	8.09	0.25	1.00	1.00	2.53	0.50	2.70	0.50	1.00	0.50
6281	JUL 4	0200	31000	2.05	0.25	4.37	1.66	2.32	1.21	1.25	0.50	2.79	0.50	6.33	0.52	12.33	0.25	2.11	1.00	2.94	0.50	2.99	0.50	1.00	1.00
6283	JUL 4	0400	23400	0.50	0.25	1.90	0.50	0.50	1.00	2.39	1.20	0.50	0.50	1.06	0.25	5.06	0.25	1.00	1.00	1.10	0.50	4.16	0.50	1.00	1.00
6285	JUL 4	0600	24600	1.27	0.25	1.00	0.50	2.62	1.00	0.50	1.00	2.30	0.50	3.56	0.25	10.64	0.25	3.64	1.00	2.57	0.50	2.76	0.50	1.00	0.50
6287	JUL 4	0800	31200	0.90	0.25	2.65	0.50	0.50	1.00	0.50	0.50	1.21	0.50	16.19	0.25	23.10	0.25	1.00	1.00	5.00	0.50	10.02	0.50	1.00	0.50
6289	JUL 4	1000	43200	0.60	0.25	1.90	0.50	0.50	0.50	1.00	0.50	1.03	0.50	2.73	0.50	302.40	0.25	2.26	1.00	58.98	0.50	124.67	0.50	1.00	1.00
6291	JUL 4	1200	53400	1.47	0.25	1.00	0.50	14.59	1.00	0.50	0.50	2.14	0.50	6.35	0.50	42.17	0.25	5.77	0.50	9.25	0.50	11.78	0.50	1.00	0.50
6293	JUL 4	1400	43000	1.14	0.25	4.14	0.50	3.00	1.00	1.00	0.50	4.03	0.50	16.44	0.50	32.50	0.50	2.00	0.50	6.93	0.25	10.52	0.25	6.47	1.30
6295	JUL 4	1600	39000	0.50	0.50	5.49	1.00	0.50	0.50	1.00	0.50	1.00	0.50	3.66	0.50	6.25	0.50	0.50	0.50	1.61	0.78	3.35	1.16	1.00	1.00
6297	JUL 4	1800	40000	1.10	0.25	5.76	2.00	0.50	0.50	1.00	0.50	1.02	0.50	6.50	0.50	43.94	0.50	1.00	0.50	11.21	1.04	16.04	1.57	1.00	1.30
6299	JUL 4	2000	43200	1.17	0.25	3.76	0.50	2.30	1.22	4.16	1.16	1.09	0.50	3.72	0.25	3.02	0.50	2.11	1.00	0.50	1.14	1.06	0.25	1.42	1.00
6301	JUL 4	2200	35400	2.32	0.25	2.09	0.50	9.11	1.26	0.50	0.50	1.00	0.50	9.00	0.25	5.00	0.25	1.25	1.00	1.24	0.50	2.92	0.50	7.34	2.93
6303	JUL 4	2400	34000	1.22	0.25	2.17	0.50	9.11	1.34	0.50	0.50	1.25	0.50	2.20	0.25	3.79	0.25	1.00	1.00	0.93	0.50	1.93	0.50	9.63	1.47
6305	JUL 5	0200	27000	1.70	0.25	1.33	0.50	5.90	1.14	1.00	0.50	1.22	0.50	4.60	0.25	22.09	0.25	0.50	1.00	0.79	0.50	12.95	0.50	1.00	1.53
6307	JUL 5	0400	24600	1.08	0.25	2.40	0.50	1.00	1.00	3.20	0.50	0.50	0.50	5.91	0.25	3.26	0.50	0.50	1.00	0.50	0.25	0.25	0.50	0.50	0.50
6309	JUL 5	0600	23400	1.02	0.25	0.50	0.50	4.54	1.20	1.43	0.50	1.00	0.50	1.95	0.25	7.11	1.06	0.50	1.00	2.01	0.50	1.61	0.25	1.02	0.50
6311	JUL 5	0800	22000	1.38	0.05	0.50	0.50	6.03	0.50	0.50	2.04	1.00	0.50	1.05	0.25	5.23	0.25	0.50	1.00	1.39	0.50	1.03	0.50	3.21	1.00
6313	JUL 5	1000	33000	1.33	0.50	9.49	1.04	0.73	1.00	0.50	1.06	1.00	0.50	2.06	0.50	7.74	0.50	1.00	1.00	1.95	0.50	1.84	0.50	1.00	1.00
6315	JUL 5	1200	44400	1.13	0.50	1.43	0.50	0.50	0.50	5.23	0.50	1.54	0.50	3.17	0.50	13.26	0.50	0.50	1.00	3.27	0.50	4.54	0.50	1.00	1.00
6317	JUL 5	1400	44400	3.53	0.50	10.78	1.00	4.28	0.50	1.15	0.50	1.66	0.50	22.74	0.50	53.28	0.50	1.79	1.00	12.60	0.50	15.50	0.50	3.88	1.00
6319	JUL 5	1600	38400	1.31	0.50	2.10	0.50	4.19	0.50	1.14	0.50	1.60	0.50	5.06	0.25	10.96	0.50	1.00	1.00	2.68	0.50	5.13	0.50	1.26	1.00
6321	JUL 5	1800	35400	0.94	0.50	7.12	0.50	9.40	0.50	0.50	1.20	1.72	0.50	2.43	0.50	7.60	0.50	1.30	1.00	1.87	0.50	3.57	0.50	1.54	1.00
6323	JUL 5	2000	34000	0.84	0.50	6.36	0.50	3.26	0.50	0.50	0.50	1.00	0.50	1.90	0.25	4.77	0.25	1.00	1.00	1.22	0.50	2.47	0.50	1.59	1.00
6325	JUL 5	2200	35400	1.19	0.50	1.90	[illegible]	2.66	1.00	0.50	0.50	1.00	1.37	2.27	0.50	4.37	0.50	0.50	1.00	1.19	0.25	1.97	0.25	3.87	1.71
6327	JUL 5	2400	33600	1.20	0.50	2.31	1.00	2.03	1.00	1.06	0.50	1.29	1.11	2.28	0.25	5.91	0.53	1.00	1.00	1.24	0.50	4.61	0.25	1.36	0.50
6329	JUL 6	0200	29400	0.92	0.50	2.51	0.50	7.16	1.00	0.50	0.50	1.00	0.50	1.45	0.25	3.29	0.50	1.00	1.00	0.73	0.50	1.14	0.25	1.92	1.26
6331	JUL 6	0400	25000	1.15	0.25	1.41	0.50	4.67	0.50	1.14	0.50	1.00	0.50	1.37	0.25	2.72	0.50	1.00	1.00	0.60	0.50	0.78	0.50	1.06	1.00
6333	JUL 6	0600	22000	0.50	0.25	1.16	0.50	4.26	1.00	2.00	0.50	0.50	0.50	0.72	0.25	2.80	0.25	1.00	1.00	0.59	0.50	0.76	0.50	1.00	1.02
6335	JUL 6	0800	23400	0.74	0.25	1.42	0.50	4.56	1.00	1.00	0.50	0.50	0.50	1.69	0.25	2.75	0.25	1.00	1.00	0.54	0.50	0.69	0.50	7.15	1.26
6337	JUL 6	1000	31200	0.61	0.25	0.50	0.50	6.60	1.00	0.50	0.50	1.00	0.50	1.35	0.25	2.77	0.25	0.50	1.00	0.25	0.50	0.93	0.50	1.00	0.50

VOLATILE ORGANICS, WATERLOO WPCP
PROJECT 431

FILENAME : WATVOLA.WK1

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (M^3/D)	BENZENE IN	BENZENE OUT	CHLOROFORM IN	CHLOROFORM OUT	1,4-DICHLOROBENZENE IN	1,4-DICHLOROBENZENE OUT	1,1,1-TRICHLOROETHANE IN	1,1,1-TRICHLOROETHANE OUT	TRICHLOROETHYLENE IN	TRICHLOROETHYLENE OUT	TOLUENE IN	TOLUENE OUT	PAR - XYLENE IN	PAR - XYLENE OUT	TETRACHLORO ETHYLENE IN	TETRACHLORO ETHYLENE OUT	ETHYL BENZENE IN	ETHYL BENZENE OUT	O-XYLENE IN	O-XYLENE OUT	1,2-DICHLORO BENZENE IN	1,2-DICHLORO BENZENE OUT
6339	JUL 6	1200	49200	1.09	0.50	1.78	1.57	0.50	0.50	0.50	0.50	[illegible]	0.50	5.16	0.76	9.43	1.27	1.00	1.00	1.94	0.25	4.96	0.25	1.00	1.26
6341	JUL 6	1400	42000	1.54	0.25	2.42	0.50	0.50	0.50	0.50	0.50	1.90	0.50	4.20	0.25	5.59	0.50	1.00	1.00	1.39	0.50	2.54	0.50	1.00	1.00
6343	JUL 6	1600	36000	1.60	0.25	2.54	0.50	1.18	0.50	1.74	1.20	1.20	0.50	1.00	0.25	2.99	0.25	0.50	1.00	0.57	0.50	1.30	0.50	1.00	1.00
6345	JUL 6	1800	27600	0.22	0.25	3.54	0.50	2.24	1.00	1.37	1.69	1.90	0.50	63.75	0.25	42.24	0.50	2.00	1.00	9.41	0.50	16.19	0.50	1.00	1.00
6347	JUL 6	2000	44300	1.33	0.25	2.52	0.50	3.26	1.00	1.19	0.50	1.42	0.50	4.04	0.25	3.41	0.25	2.19	1.00	0.25	0.50	2.28	0.50	0.50	0.50
6349	JUL 6	2200	41400	1.18	0.25	1.41	0.50	3.30	1.00	0.50	0.50	0.50	0.50	1.56	0.25	2.00	0.25	1.56	1.00	0.25	0.50	2.33	0.50	1.20	1.00
6351	JUL 6	2400	39700	1.11	0.25	3.27	0.50	0.50	0.50	0.50	1.26	0.50	0.50	1.00	0.25	2.43	0.25	1.00	1.00	0.25	0.50	1.64	0.50	1.00	1.00
6353	JUL 7	0200	32400	1.16	0.25	0.50	0.50	0.50	0.50	1.05	1.00	0.50	0.50	2.91	0.25	1.96	0.25	1.00	1.00	0.25	0.50	0.66	0.50	1.00	1.00
6355	JUL 7	0400	28400	1.24	0.25	1.22	0.50	3.74	1.00	1.63	0.50	0.50	0.50	4.71	0.25	1.74	0.25	1.00	1.00	0.25	0.50	0.25	0.50	1.07	1.00
6357	JUL 7	0600	28000	1.10	0.25	0.50	0.50	3.40	1.00	0.50	0.50	0.50	0.50	3.90	0.25	2.05	0.25	1.00	1.00	0.50	0.50	0.00	0.50	1.00	1.00
6359	JUL 7	0800	30300	0.89	0.25	3.25	0.50	0.50	1.00	1.13	0.50	0.50	0.50	3.60	0.25	1.82	0.25	1.00	1.00	0.50	0.50	0.57	0.50	1.00	1.00
6361	JUL 7	1000	48000	1.17	0.25	2.41	0.50	8.21	1.00	1.05	0.50	4.32	0.50	10.14	0.25	3417.00	0.25	1.95	1.00	690.70	0.50	907.30	0.50	1.30	0.50
6363	JUL 7	1200	57600	1.18	0.25	3.42	0.50	3.00	1.00	0.50	0.50	2.50	0.50	1.65	0.25	2.96	0.50	1.00	1.00	0.71	0.50	1.53	0.50	0.50	0.50
6365	JUL 7	1400	56400	1.53	0.25	5.19	0.50	0.50	0.50	4.47	2.14	2.29	0.50	8.79	0.25	10.50	0.25	0.50	1.00	2.10	0.50	6.70	0.50	1.00	1.00
6367	JUL 7	1600	58000	1.30	0.25	10.64	1.63	1.00	1.00	1.00	2.70	2.37	0.50	7.71	0.25	21.06	0.25	2.94	1.00	3.75	0.50	9.74	0.50	0.50	0.50
6369	JUL 7	1800	49200	0.92	0.25	0.50	1.95	0.50	0.50	1.00	0.50	1.94	0.50	4.05	0.25	8.89	0.25	1.19	1.00	1.89	0.50	8.05	0.50	1.00	1.00
6371	JUL 7	2000	46000	1.13	0.25	108.30	1.70	4.24	1.04	1.33	0.50	2.05	0.50	2.60	0.25	5.44	0.25	1.17	1.00	1.21	0.50	4.14	0.50	1.55	1.20
6373	JUL 7	2200	46000	3.18	0.25	3.40	1.73	6.32	1.11	1.71	0.50	3.44	0.50	19.17	0.25	23.63	0.50	1.02	1.00	5.12	0.50	11.61	0.25	1.96	1.00
6375	JUL 7	2400	46200	1.51	0.25	4.59	1.70	3.43	1.03	1.92	0.50	2.28	0.50	5.19	0.25	10.16	0.25	0.50	1.00	2.02	0.50	4.92	0.50	0.50	0.50
6377	JUL 8	0200	37200	0.70	0.25	3.53	1.50	1.00	1.00	2.33	0.50	1.60	0.50	1.41	0.25	2.67	0.25	1.00	1.00	0.25	0.50	1.18	0.50	0.50	0.50
6379	JUL 8	0400	29400	1.10	0.25	1.37	1.57	1.00	1.00	1.50	0.50	1.00	0.50	3.40	0.25	14.97	0.25	1.45	1.00	3.49	0.50	2.65	0.50	1.00	1.00
6381	JUL 8	0600	31200	0.99	0.25	6.96	1.30	4.30	1.00	1.89	0.50	1.90	0.50	1.99	0.25	6.73	0.25	1.45	1.00	1.72	0.50	1.33	0.50	1.00	1.00
6383	JUL 8	0800	36000	0.59	0.25	7.79	1.90	0.50	2.00	1.05	1.02	3.51	0.50	1.29	0.25	3.24	0.25	0.50	1.00	9.25	0.50	1.00	0.50	1.00	1.40
6385	JUL 8	1000	49000	0.59	0.25	5.75	1.63	1.02	0.50	2.98	0.50	2.09	0.50	4.44	1.03	17.14	0.50	1.26	1.00	3.93	0.50	3.53	0.50	1.00	1.00
6387	JUL 8	1200	52000	0.62	0.25	1.32	1.46	2.48	1.06	2.51	0.50	1.02	0.50	3.96	0.25	9.55	0.25	1.76	1.00	2.34	0.50	3.44	0.50	1.00	0.50
6389	JUL 8	1400	47400	3.59	0.25	24.54	1.28	0.50	1.02	2.93	0.50	5.11	0.50	3.51	0.25	10.40	0.25	1.33	1.00	2.72	0.50	3.66	0.50	1.00	1.00
6391	JUL 8	1600	47400	1.21	0.25	10.13	1.96	2.33	1.10	2.62	0.50	4.06	0.50	2.05	0.25	9.13	0.25	1.42	1.00	3.56	0.50	5.54	0.50	1.00	1.00
6393	JUL 8	1800	45600	1.76	0.25	3.31	2.02	0.50	1.00	2.73	0.50	2.26	0.50	4.77	0.25	52.07	0.25	1.17	1.00	12.81	0.50	9.74	0.50	1.00	1.00
6395	JUL 8	2000	49200	0.81	0.25	21.54	1.90	0.50	1.00	1.24	0.50	2.00	0.50	1.75	0.25	11.92	0.25	0.50	1.00	2.00	0.50	5.46	0.50	1.00	1.00
6397	JUL 8	2200	45600	1.08	0.25	4.05	2.38	5.43	1.00	2.44	0.50	1.30	0.50	5.03	0.25	8.97	0.25	1.06	1.00	1.93	0.50	7.32	0.50	1.00	1.00
6399	JUL 8	2400	45600	2.05	0.25	2.24	1.50	13.06	1.23	0.50	0.50	1.06	0.50	2.28	0.25	4.04	0.25	1.32	1.00	0.25	0.50	2.30	0.50	1.00	1.00
6401	JUL 9	0200	38400	0.89	0.25	2.22	1.60	0.50	0.50	0.50	0.50	1.20	0.50	0.10	0.25	47.77	0.25	1.02	1.00	12.26	0.50	6.19	0.50	1.00	1.00
6403	JUL 9	0400	30000	5.53	0.25	5.44	2.64	0.50	0.50	2.16	0.50	8.04	0.50	5.07	0.25	12.23	1.00	1.10	1.00	2.40	0.50	9.91	0.50	1.00	1.00
6405	JUL 9	0600	31000	1.32	0.25	0.50	0.50	0.50	0.50	1.00	0.50	1.56	0.50	1.65	0.25	4.12	0.25	3.14	1.00	0.25	0.50	3.89	0.50	1.00	1.00
6407	JUL 9	0800	37200	0.77	0.25	1.03	0.50	5.10	0.50	1.47	0.50	0.50	0.50	1.43	0.25	2.96	0.25	1.00	1.00	0.50	0.50	0.25	0.50	1.00	1.00
6409	JUL 9	1000	51600	0.00	0.25	5.41	0.50	0.50	0.50	1.40	1.04	1.00	0.50	2.76	0.25	14.23	0.25	0.50	1.00	2.07	0.50	0.23	0.50	1.00	1.00
6411	JUL 9	1200	52000	2.03	0.25	3.24	0.50	3.29	0.50	1.40	0.50	0.50	0.50	8.65	0.25	15.23	0.25	2.19	1.00	3.40	0.50	3.50	0.50	1.22	1.00
6413	JUL 9	1400	51000	4.15	0.25	4.67	0.50	0.50	0.50	1.20	1.47	0.50	0.50	3.74	1.10	12.17	0.51	3.31	1.00	2.77	0.50	2.70	0.50	1.00	1.00
6415	JUL 9	1600	48000	2.33	0.25	12.56	0.50	5.00	1.00	1.20	1.03	1.27	0.50	2.79	0.25	13.30	0.25	1.30	1.00	3.13	0.50	7.52	0.50	2.75	0.50
6417	JUL 9	1800	48600	6.09	0.50	12.23	0.50	4.46	1.00	1.15	0.50	1.92	0.50	3.03	0.25	9.49	0.50	0.50	1.00	2.39	0.50	4.14	0.25	1.00	1.00
6419	JUL 9	2000	53400	0.84	0.25	6.05	0.50	2.51	1.01	1.40	0.50	1.05	0.50	1.67	0.25	7.13	0.50	3.51	1.00	1.69	0.50	2.02	0.50	1.00	1.00
6421	JUL 9	2200	43000	3.12	0.25	4.17	0.50	0.50	1.04	1.34	0.50	4.20	0.50	2.76	0.25	20.12	0.25	1.00	1.00	5.05	0.50	7.31	0.50	1.00	1.00
6423	JUL 9	2400	46200	1.50	0.50	4.72	1.97	0.50	0.50	1.17	1.24	1.16	0.50	2.15	0.25	14.23	0.50	2.13	1.00	3.22	0.50	5.73	0.50	1.00	1.00
6425	JUL 10	0200	42000	1.30	0.25	17.27	1.32	1.00	1.00	1.00	1.00	1.84	0.50	1.89	0.25	5.56	0.25	4.14	1.00	1.17	0.50	1.50	0.50	1.00	1.00
6427	JUL 10	0400	30000	1.72	0.25	4.19	0.50	0.50	1.00	2.58	0.50	0.50	0.50	9.20	0.25	3.99	2.14	1.03	1.00	0.92	0.50	1.01	0.50	1.00	1.00
6429	JUL 10	0600	31000	1.13	0.25	4.52	1.06	0.50	1.00	1.47	0.50	1.00	0.50	1.54	0.25	2.57	0.50	1.00	1.00	0.50	0.50	0.50	0.50	1.00	1.00
6431	JUL 10	0800	37000	0.92	0.25	1.22	1.90	0.50	0.50	1.50	0.50	3.02	0.50	1.06	0.50	1.67	0.50	1.00	1.00	0.50	0.50	0.50	0.50	1.00	1.00
6433	JUL 10	1000	54000	1.32	0.25	2.21	1.00	0.50	0.50	1.00	1.70	1.35	0.50	3.41	0.25	4.76	0.25	1.00	1.00	1.06	0.50	2.70	0.50	1.00	1.00

VOLATILE ORGANICS, WATERLOO WPCP
PROJECT 431

FILENAME : WATVOLA.WK1

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (M^3/D)	BENZENE		CHLOROFORM		1,4-DICHLOROBENZENE		1,1,1-TRICHLOROETHANE		TRICHLOROETHYLENE		TOLUENE		P&M - XYLENE		TETRACHLORO ETHYLENE		ETHYL BENZENE		O-XYLENE		1,2-DICHLORO BENZENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
0435	JUL 10	1200	56400	1.00	0.25	2.19	1.29	0.50	1.00	0.50	0.50	2.31	0.50	1.59	0.25	3.06	0.25	2.01	1.00	0.25	0.50	3.01	0.50	1.00	1.00
0437	JUL 10	1400	54000																						
0439	JUL 10	1600	48600																						
Num Data Points			99	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Average			38674	1.09	0.30	5.10	1.02	2.94	0.89	1.39	0.72	1.71	0.53	5.03	0.32	50.38	0.43	1.37	0.98	10.40	0.51	15.22	0.51	1.56	0.96
Std. Deviation			9373	1.56	0.10	11.25	0.66	3.05	0.31	0.99	0.43	1.53	0.16	7.32	0.18	347.02	0.54	1.01	0.10	70.12	0.12	92.48	0.21	1.84	0.32
Minimum Value			22000	0.50	0.25	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.72	0.25	1.50	0.25	0.50	0.50	0.25	0.25	0.25	0.25	0.50	0.50
Maximum Value			58000	8.84	0.85	106.30	2.80	14.50	2.00	5.23	2.70	11.28	1.71	63.75	1.18	3417.00	4.70	5.77	1.00	690.70	1.14	907.30	1.92	12.35	2.93

FILENAME : WELLCONC.WK1

WELLAND WPCP : ANALYTICAL DATA
PROJECT : 431

05/30/88

SAMPLE DATE TIME	FLOW	UNITS : mg/L										UNITS : ug/L								UNITS : mg/L				UNITS : ug/L				UNITS : ug/L	
I.D.	(m^3/day)	BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		PHENOLICS	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
0451 AUG 19 0800	19475			10.0	9.4					12	6	4	4	10	10	12	6	17	18	1.09	0.99	1.07	0.60	5	5	37	25	3.4	2.4
0453 AUG 19 1000	34313			11.1	9.0	16.4			2.9	40	5	3	3	11	10	19	5	14	17	2.49	0.92	1.33	0.47	5	5	45	25	8.4	3.4
0455 AUG 19 1200	32040			22.4	8.6	20.4		20.0	2.1	70	4	2	3	11	8	30	6	17	15	4.41	0.75	2.00	0.47	10	5	73	20	12.0	4.0
0457 AUG 19 1400	39496			44.3	8.5					80	4	4	3	10	8	30	4	16	16	5.39	0.71	2.93	0.43	10	5	82	19	17.2	4.0
0459 AUG 19 1600	33331			53.5	8.5	20.2			3.1	120	4	3	4	11	9	51	8	14	17	5.51	0.78	3.20	0.40	15	5	99	19	18.0	1.4
0461 AUG 19 1800	34259	120	2.0	42.1	9.1					70	4	3	3	10	8	30	4	16	14	4.01	0.81	2.93	0.57	10	5	79	12	10.0	1.0
0463 AUG 19 2000	25749			29.4	9.1	18.0			5.0	90	4	3	2	9	8	31	6	9	11	4.23	0.86	2.53	0.57	10	5	59	31	9.5	1.0
0465 AUG 19 2200	20512			29.5	9.1					90	5	2	3	9	9	30	5	16	16	4.78	0.99	3.07	0.70	5	5	65	30	14.8	2.8
0467 AUG 19 2400	24494			27.9	8.9	20.0	6.0		4.0	80	5	3	2	14	8	31	8	14	14	5.17	0.94	3.20	0.80	10	5	53	23	27.1	1.0
0469 AUG 20 0200	18275			20.0	8.9					50	5	2	2	8	8	24	6	10	18	4.35	0.92	2.93	0.63	5	5	40	36	21.6	1.0
0471 AUG 20 0400	15111	70	2.4	17.8	9.0	19.0			3.0	50	4	3	2	13	6	22	3	12	12	3.44	0.87	2.13	0.53	5	5	29	36	13.4	5.0
0473 AUG 20 0600	10030			12.6	8.4					30	4	2	1	8	8	17	5	11	12	2.53	0.95	1.60	0.60	5	5	71	30	6.7	2.4
0475 AUG 20 0800	21930			13.3	8.2	19.4	3.0		2.9	50	3	2	1	16	6	15	3	12	11	2.21	0.82	1.20	0.63	5	5	70	21	5.4	3.5
0477 AUG 20 1000	31967			16.6	8.1					20	4	1	1	9	8	22	7	7	11	3.66	0.94	2.00	0.53	5	5	66	20	10.2	5.0
0479 AUG 20 1200	35077			67.6	8.9	40.0		24.0	1.0	150	4	2	2	12	8	48	8	14	17	7.19	0.89	0.26	0.63	5	5	231	30	22.6	4.0
0481 AUG 20 1400	30167			75.0	8.6					90	3	1	2	9	8	41	3	10	12	6.29	0.85	2.27	0.53	5	5	111	14	10.1	3.4
0483 AUG 20 1600	27440			41.9	9.0	28.0			3.2	80	3	2	4	10	10	41	5	14	13	5.43	0.84	2.93	0.57	10	5	102	40	21.0	2.4
0485 AUG 20 1800	33004			61.8	9.2					80	4	3	4	9	9	32	4	12	17	5.43	0.94	2.67	0.60	5	5	74	24	14.7	1.0
0487 AUG 20 2000	26567			40.0	9.0	22.0			5.1	100	3	5	5	12	14	30	7	14	18	4.74	1.23	2.67	0.63	5	5	65	45	87.5	1.0
0489 AUG 20 2200	20531			34.1	9.3					80	5	4	3	12	11	41	7	14	16	5.22	1.15	2.80	0.60	5	5	71	24	16.4	1.0
0491 AUG 20 2400	24439			20.5	8.9	23.0			5.1	40	4	4	3	15	11	41	5	17	14	5.01	1.17	2.80	0.80	5	5	90	19	14.6	1.0
0493 AUG 21 0200	19257			23.0	8.8					20	3	4	3	49	9	25	4	12	13	4.50	0.92	2.67	0.53	5	5	53	57	12.0	5.1
0495 AUG 21 0400	14947			16.2	9.0	22.0		13.2	4.6	13	3	3	1	13	8	17	7	14	9	3.45	0.92	1.07	0.67	5	5	39	23	13.6	2.4
0497 AUG 21 0600	16202			13.4	8.4					4	3	3	3	27	9	21	3	12	12	2.40	0.89	1.60	0.50	5	5	30	27	10.0	3.4
0499 AUG 21 0800	23730			13.5	8.5	23.2			3.4	7	2	3	4	10	9	11	4	12	12	1.90	0.25	1.20	0.57	5	35	63	12	7.5	3.4
0501 AUG 21 1000	37259			17.7	8.4					34	2	9	2	60	11	61	4	34	12	3.47	0.83	1.73	0.53	5	5	66	19	10.4	0.5
0503 AUG 21 1200	32706	120	2.2	22.5	7.1	32.8	3.3		2.3	87	2	3	4	16	11	40	7	12	18	5.94	0.95	3.20	0.50	10	5	105	16	12.0	2.4
0505 AUG 21 1400	38823			27.4	7.3					90	3	4	3	15	10	36	4	14	12	5.63	0.85	2.93	0.53	10	5	80	17	9.4	1.0
0507 AUG 21 1600	83519			11.7	7.1	9.2			4.3	90	4	2	3	20	12	49	4	26	15	1.47	0.95	0.67	0.57	80	5	190	36	1.4	1.0
0509 AUG 21 1800	91265			14.2	7.7					70	4	2	3	15	9	29	4	19	13	1.02	1.02	0.67	0.73	30	5	161	30	5.4	1.0
0511 AUG 21 2000	97266			18.2	8.6	12.9			5.2	66	5	4	2	23	8	30	5	20	14	2.60	0.89	1.33	0.53	15	5	110	15	0.0	1.0
0513 AUG 21 2200	36332			19.2	9.1					260	13	4	3	25	16	64	5	21	16	4.44	0.94	2.13	0.57	40	5	104	22	12.0	3.2
0515 AUG 21 2400	88846			21.5	9.0	18.6			4.9	70	7	3	2	16	12	31	6	18	16	3.05	0.88	2.40	0.50	5	5	77	28	10.8	1.1
0517 AUG 22 0200	23640			17.6	8.8					30	8	4	4	15	9	23	4	10	13	3.09	0.90	2.53	0.53	5	5	48	20	12.9	7.6
0519 AUG 22 0400	17940			13.0	8.5	16.0			4.0	50	6	3	3	23	9	19	6	20	13	2.92	0.86	1.73	0.53	5	5	36	25	12.2	0.0
0521 AUG 22 0600	14961	60	3.5	10.1	8.4					40	5	4	3	15	11	13	4	13	13	2.24	0.77	1.33	0.47	5	5	34	18	7.6	3.2
0523 AUG 22 0800	15752			8.1	9.2	16.1			7.3	8	4	4	4	13	7	14	6	12	10	1.77	0.85	1.07	0.50	5	5	25	22	5.1	5.0
0525 AUG 22 1000	23021			9.0	8.2					30	2	5	4	20	17	17	11	16	18	2.09	0.80	1.20	0.40	5	5	42	20	10.0	3.4
0527 AUG 22 1200	61310			16.1	8.3	20.4			2.4	60	4	4	3	23	11	43	8	18	23	4.37	0.77	2.53	0.47	5	10	84	37	1.4	5.0
0529 AUG 22 1400	31250			68.7	8.3					100	3	4	3	15	11	43	7	15	16	6.95	0.74	2.67	0.40	10	5	89	29	25.0	4.0
0531 AUG 22 1600	25912			69.2	8.2	25.1			4.3	110	3	5	3	18	11	46	4	17	14	5.66	0.83	2.53	0.40	5	5	86	21	15.4	4.0
0533 AUG 22 1800	31477			57.7	8.2					80	3	3	3	15	15	44	11	14	16	5.59	0.77	3.47	0.53	5	5	190	19	26.4	2.4
0535 AUG 22 2000	27931			20.3	7.6	19.6	6.4		6.3	50	3	8	4	34	11	57	10	25	13	4.20	0.92	2.67	0.53	5	5	51	31	13.0	2.6
0537 AUG 22 2200	26985			61.7	8.7					60	3	4	3	17	9	30	9	13	13	4.74	0.94	3.60	0.67	5	5	47	21	15.5	2.0
0539 AUG 22 2400	21875			24.1	8.3	21.9		14.0	8.9	40	4	4	4	13	11	20	4	13	17	4.45	0.94	2.93	0.70	5	5	50	21	13.5	1.0
0541 AUG 23 0200	17457	60	2.0	20.2	7.9					40	3	5	4	23	10	27	8	12	13	4.41	0.93	3.60	0.60	5	5	30	25	10.0	1.0
0543 AUG 23 0400	14511			15.8	7.9	20.6			6.3	30	3	2	4	11	12	19	8	9	14	3.91	0.99	2.53	0.67	5	5	30	21	11.3	1.0
0545 AUG 23 0600	15220			12.2	7.6					20	3	5	4	15	11	20	4	18	16	3.10	0.95	2.13	0.57	5	5	30	18	8.4	3.3

FILENAME : WELLCONC.WK1

WELLAND WPCP : ANALYTICAL DATA
PROJECT : 431

05/30/88

SAMPLE	DATE	TIME	FLOW		UNITS : mg/L									UNITS : mg/L								UNITS : mg/L				UNITS : mg/L				UNITS : mg/L	
I.D.			(m^3/day)	BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		PHENOLICS	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
0547	AUG 23	0800	19630			9.7	7.2	15.3		13.0	4.0	16	5	4	3	14	10	14	6	14	14	2.21	0.85	1.33	0.60	5	5	20	20	1.0	1.3
0549	AUG 23	1000	29705			12.7	7.5					50	3	4	3	13	10	19	4	14	16	2.05	0.91	2.13	0.57	5	5	43	20	1.0	1.0
0551	AUG 23	1200	34095			18.3	7.3	33.6			3.1	60	4	2	2	11	9	35	5	13	14	5.08	0.92	3.20	0.57	5	5	75	18	13.0	1.0
0553	AUG 23	1400	30732			26.4	7.0					80	3	2	3	10	10	34	5	11	14	5.97	0.83	3.33	0.53	5	5	73	17	10.0	1.0
0555	AUG 23	1600	60135			13.1	7.1	12.0	10.2		4.4	170	3	2	2	22	10	46	12	25	15	2.12	0.95	1.07	0.57	95	5	175	36	6.0	14.1
0557	AUG 23	1800	63000			14.3	7.7					70	5	2	2	10	9	26	11	14	12	1.79	1.00	0.53	0.67	35	5	135	20	2.0	1.0
0559	AUG 23	2000	64062			13.9	7.4	9.0			5.0	60	6	2	2	10	10	27	6	15	14	1.96	1.06	0.67	0.57	15	5	99	22	1.0	5.4
0561	AUG 23	2200	60662			12.7	7.4					40	5	2	1	15	7	19	6	13	9	1.75	0.94	1.07	0.57	15	5	92	26	3.6	4.4
0563	AUG 23	2400	53097			14.9	7.4	12.0			3.4	50	4	2	2	10	8	24	7	11	15	2.57	0.89	1.20	0.57	10	5	62	20	6.6	2.1
0565	AUG 24	0200	54170			18.1	7.0					50	4	2	2	13	8	31	5	13	12	3.09	0.83	1.07	0.60	15	5	62	19	8.0	3.4
0567	AUG 24	0400	28021			15.0	7.2	22.2		13.0	3.0	290	3	3	2	21	8	93	6	23	11	5.74	0.81	2.27	0.53	75	5	105	22	1.0	1.6
0569	AUG 24	0600	17566			11.0	6.9					40	4	2	1	14	8	29	5	15	11	2.46	0.84	1.60	0.67	10	5	50	20	5.0	6.0
0571	AUG 24	0800	14729			9.1	7.0	13.4			2.7	10	2	2	2	14	8	16	8	22	9	1.83	0.81	1.33	0.57	5	5	30	25	14.2	7.4
0573	AUG 24	1000	35095			16.7	7.2					30	3	3	2	14	6	35	4	15	12	3.51	0.85	2.00	0.55	5	5	52	17	7.5	2.4
0575	AUG 24	1200	37041			22.7	6.9	29.4			1.0	80	4	2	2	12	8	36	8	15	13	4.01	0.86	0.67	0.53	10	5	60	16	18.0	3.4
0577	AUG 24	1400	30767	130	2.0	30.0	7.3					60	3	2	2	12	9	42	9	13	10	6.06	0.81	3.73	0.50	5	5	66	19	18.4	5.0
0579	AUG 24	1600	29022			31.2	8.8	23.6			1.0	54	3	2	2	11	9	49	4	11	11	5.99	0.82	3.47	0.50	10	10	65	16	12.0	1.0
0581	AUG 24	1800	27050			29.5	7.2					70	2	2	2	12	10	43	8	17	13	5.06	0.81	3.07	0.60	5	5	81	25	10.0	2.6
0583	AUG 24	2000	25067			27.4	7.0	19.6		12.7	1.0	29	2	2	2	41	9	32	7	13	11	4.29	0.88	2.67	0.77	5	5	49	25	16.0	1.2
0585	AUG 24	2200	25039			29.8	8.0					33	2	2	2	12	9	37	4	12	12	5.30	0.94	3.47	0.60	10	10	40	22	13.0	3.2
0587	AUG 24	2400	22306			25.4	7.3	21.4			1.0	90	3	2	2	12	9	36	3	14	12	5.09	0.95	4.00	0.67	25	5	42	36	12.0	3.4
0589	AUG 25	0200	18011			23.7	7.0					28	3	2	2	23	9	20	4	11	12	4.50	0.90	2.80	0.57	5	5	32	16	12.0	2.4
0591	AUG 25	0400	15002			19.3	6.9	19.6			5.1	16	2	2	2	10	9	29	6	12	13	3.76	0.97	2.53	0.60	5	5	41	23	10.4	1.0
0593	AUG 25	-0600	15275			14.2	7.2					12	3	2	2	8	8	12	5	13	13	2.61	0.92	1.73	0.63	5	5	22	22	5.0	1.0
0595	AUG 25	0800	25250			12.8	8.6	14.0	4.4		3.6	10	3	3	2	31	9	13	6	13	13	2.31	0.95	1.07	0.60	5	5	24	20	6.0	1.0
0597	AUG 25	1000	35022			19.5	6.9					40	2	3	3	15	9	30	4	14	15	3.77	0.91	2.53	0.77	5	5	47	19	20.4	1.0
0599	AUG 25	1200	37960			44.1	6.7	35.7			2.5	80	2	2	2	12	9	43	4	10	10	6.45	0.84	3.47	0.57	15	5	75	17	12.0	1.0
0601	AUG 25	1400	34095			42.8	7.1					100	2	2	2	14	9	47	5	9	11	6.44	0.85	3.60	0.53	15	5	75	21	15.7	1.0
0603	AUG 25	1600	39004	230	2.2	97.6	7.6	30.0			4.0	360	3	3	2	15	8	54	6	11	8	7.00	0.94	1.33	0.60	25	5	110	34	14.0	1.0
0605	AUG 25	1800	28907			65.0	7.9					290	2	1	1	10	8	50	6	8	7	6.23	0.95	1.00	0.60	15	5	88	17	20.0	1.3
0607	AUG 25	2000	29294			33.2	8.1	21.0		14.2	7.0	70	3	3	3	15	10	46	5	14	12	5.27	1.35	2.67	0.77	10	5	69	23	25.9	1.0
0609	AUG 25	2200	25470			35.6	9.1					70	5	2	3	12	9	41	6	11	12	5.91	1.07	3.47	1.00	10	5	59	18	16.0	3.0
0611	AUG 25	2400	23294			30.9	9.2	23.4			7.3	50	6	2	3	13	9	35	11	20	11	5.30	1.02	3.47	1.13	5	5	51	27	10.0	1.0
0613	AUG 26	0200	17340			22.5	8.7					150	4	3	2	12	9	32	4	12	11	5.15	1.64	3.20	0.87	5	5	45	21	14.4	1.0
0615	AUG 26	0400	14704			17.0	8.3	10.5			6.6	30	3	3	3	13	10	25	5	11	13	3.07	1.40	2.40	0.87	5	5	28	20	10.4	1.0
0617	AUG 26	0600	15493			13.7	7.6					16	3	3	2	13	8	16	8	14	11	3.11	1.30	2.40	0.87	5	5	30	13	9.4	1.4
0619	AUG 26	0800	24707			11.0	7.0	16.7			4.9	12	3	2	3	13	10	19	19	13	13	2.40	1.14	1.47	0.73	5	5	27	20	5.0	1.0
0621	AUG 26	1000	34095	60	2.5	16.7	7.6					70	3	3	3	14	8	35	8	47	11	3.83	1.08	2.40	0.77	5	20	63	18	13.0	1.0
0623	AUG 26	1200	33413			52.7	7.4	37.0			3.1	100	2	2	2	14	9	51	8	17	14	6.52	0.95	2.53	0.73	10	5	97	18	10.4	1.0
0625	AUG 26	1400	30440			60.7	9.8					170	2	3	2	14	10	51	5	17	13	6.46	0.92	1.33	0.60	10	5	100	18	10.0	3.4
0627	AUG 26	1600	29176			61.7	9.8	25.0	4.0		4.0	140	2	3	2	14	10	56	6	17	13	5.07	0.94	1.47	0.63	15	5	144	20	17.0	2.4
0629	AUG 26	1800	75230			90.9	10.6					110	3	3	2	43	9	49	7	14	13	6.37	0.99	1.20	0.60	10	5	111	22	10.0	3.0
0631	AUG 26	2000	121100			22.0	11.1	22.0			5.5	290	12	2	2	36	8	103	12	31	13	4.11	1.21	0.93	0.63	80	5	355	40	0.4	3.0
0633	AUG 26	2200	105613			14.0	11.1					200	8	3	3	10	9	56	8	19	13	2.81	0.99	1.07	0.63	40	5	158	21	5.4	3.0
0635	AUG 26	2400	62044			13.0	9.9	8.4			5.0	60	6	3	2	21	14	29	15	20	15	1.58	0.88	1.07	0.53	25	5	77	22	2.6	4.0
0637	AUG 27	0200	50316			11.9	9.2					60	5	3	2	10	8	24	8	11	12	1.52	0.81	0.93	0.57	20	5	60	22	3.4	1.4
0639	AUG 27	0400	52679			13.1	8.7	9.4	4.1		2.4	20	5	2	2	12	6	18	4	12	11	1.74	0.69	0.93	0.37	10	5	65	14	2.0	2.4
0641	AUG 27	0600	49042			11.2	8.6					30	5	2	2	12	7	20	8	12	11	1.06	0.60	1.20	0.33	5	5	47	16	13.7	1.4
0643	AUG 27	0800	49042	30	2.4	10.7	8.3	11.4		7.1	1.4	80	4	3	2	39	7	29	9	20	13	1.81	0.62	0.67	0.30	15	5	77	14	3.2	1.0

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     FILENAME : WELLCONC.WK1                                        WELLAND WPCP : ANALYTICAL DATA
                                                                    PROJECT      : 431                                                   05/30/88
                                                                    ------------------------------------

                   :           :                                  :                                      :                         :                          :               :
                   :           :           UNITS : mg/L           :           UNITS : ug/L               :      UNITS : mg/L       :      UNITS : ug/L        : UNITS : ug/L  :
 SAMPLE DATE  TIME :   FLOW    :  BOD    TOC    TKN    NH3-N  TSS :  Cd      Cr        Cu         Ni     :  P         FILT. P      :  Pb         Zn           :  PHENOLICS    :
  I.D.             :(m^3/day)  :IN  OUT IN  OUT IN  OUT IN  OUT IN  OUT :IN  OUT IN  OUT IN  OUT IN  OUT :IN  OUT IN  OUT :IN  OUT IN  OUT :   IN   OUT :
-------------------:-----------:----------------------------------:--------------------------------------:-------------------------:--------------------------:---------------:
  0645 AUG 27 1000 :   32349   :          14.9   0.2                          80     3 :    2    3   12    8    28     4   14    15 : 2.05 0.56 1.47 0.33 :    5    5    50    14 :  11.0   1.0 :
  0647 AUG 27 1200 :   40507   :          88.4   0.6  20.4   1.0          1.1  120     3 :    3    2   40    8    37     5   16    12 : 4.05 0.52 1.23 0.40 :    5    5    74    16 :  10.0   1.0 :

 -

Num Data Points        99 :    9    9    99    99    50     9     9    50    99    99 :   99   99    99    99     99    99    99    99 :   99   99   99   99 :   99    99     99    99 :    99    99 :
Average             34974 :101.0 2.44 28.01  0.24 21.41  4.98 14.76  3.95  73.94  3.04 : 2.91 2.57 18.46  9.27  34.12  6.28 15.09 13.26 : 4.07 0.93 2.14 0.59 :12.17  5.61  76.22 22.09 : 12.37  2.63 :
Std. Deviation      20917 :58.47 0.47 20.92  0.93  7.73  2.39  4.78  1.74  84.99  1.80 : 1.18 0.88  9.20  1.75  15.60  2.04  5.51  2.46 : 1.61 0.21 0.94 0.13 :16.31  3.45  50.94  7.61 :  8.34  2.12 :
Minimum Value       14511 :30.00 2.00  0.10  0.70  8.40  1.00  7.10  1.00   4.00  2.00 : 1.00 1.00  8.00  6.00  11.00  3.00  7.00  7.00 : 1.47 0.52 0.26 0.30 : 5.00  5.00  22.00 12.00 :  1.00  1.00 :
Maximum Value      121100 :250.0 3.50 98.90 11.10 40.00 10.20 24.00  7.30 380.00 13.00 : 9.00 5.00 80.00 17.00 103.00 19.00 47.00 23.00 : 7.80 1.07 4.00 1.13 :95.00 35.00 355.00 57.00 : 87.50 14.10 :
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VOLATILE ORGANICS. WELLAND WPCP
PROJECT 431

FILENAME : WELLVOLA.WK1 05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	CHLOROFORM		1.4-DICHLORO BENZENE		TRICHLORO ETHYLENE		TOLUENE		P&M - XYLENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
6451	AUG 19	0800	19475	5.11	1.00	1.49	1.00	0.50	0.50	0.50	0.25	0.50	0.25
6453	AUG 19	1000	34313	6.67	1.00	1.93	1.00	0.50	0.50	0.50	0.25	0.25	0.25
6455	AUG 19	1200	32840	6.70	1.00	2.34	1.00	1.00	0.50	0.50	0.25	0.25	1.94
6457	AUG 19	1400	39496	5.73	1.00	2.50	1.00	1.79	0.50	1.83	0.25	1.33	0.25
6459	AUG 19	1600	33331	6.21	1.00	2.30	1.00	5.09	0.50	1.68	0.25	1.82	0.25
6461	AUG 19	1800	34259	3.78	1.00	1.58	1.00	1.00	0.50	1.05	0.25	1.46	0.25
6463	AUG 19	2000	25749	5.62	1.00	2.36	1.00	1.76	0.50	0.95	0.25	0.61	0.25
6465	AUG 19	2200	26512	5.16	1.00	2.29	1.00	2.84	0.50	0.86	0.25	0.60	0.25
6467	AUG 19	2400	24494	4.80	1.00	2.61	1.00	2.58	0.50	0.84	0.25	0.50	0.25
6469	AUG 20	0200	18275	5.00	1.00	2.10	1.00	1.02	0.50	0.89	0.25	0.50	0.25
6471	AUG 20	0400	15111	2.75	1.00	1.58	1.00	0.50	0.50	0.63	0.25	0.25	0.25
6473	AUG 20	0600	16038	3.54	1.00	1.67	1.00	0.50	0.50	0.58	0.25	0.75	0.25
6475	AUG 20	0800	21930	3.39	1.00	1.59	1.00	0.50	0.50	0.25	0.25	0.25	0.25
6477	AUG 20	1000	31967	4.19	1.00	2.29	0.50	1.00	0.50	1.17	0.25	4.32	0.67
6479	AUG 20	1200	35077	6.93	0.50	2.79	0.50	0.50	0.50	1.63	0.25	4.92	0.50
6481	AUG 20	1400	30167	8.31	0.50	2.36	0.50	1.00	0.50	1.37	0.25	2.86	0.75
6483	AUG 20	1600	27440	7.11	0.50	2.56	0.50	4.00	0.50	2.02	0.25	1.66	0.68
6485	AUG 20	1800	33004	7.18	1.00	2.18	0.50	4.26	0.50	1.13	0.25	1.39	0.50
6487	AUG 20	2000	26567	5.39	1.00	2.30	0.50	3.00	0.50	2.60	0.25	1.25	0.50
6489	AUG 20	2200	28531	4.92	1.00	2.03	0.50	1.00	0.50	0.95	0.25	0.88	0.25
6491	AUG 20	2400	24439	6.39	1.00	2.24	0.50	1.62	0.50	1.17	0.25	0.97	0.25
6493	AUG 21	0200	19257	5.53	1.00	2.14	0.50	1.68	0.50	1.11	0.25	0.81	0.25
6495	AUG 21	0400	14947	4.71	1.00	1.87	0.50	1.00	0.50	1.54	0.25	0.25	0.25
6497	AUG 21	0600	16202	4.01	1.00	1.80	0.50	0.50	0.50	0.50	0.25	0.25	0.25
6499	AUG 21	0800	23730	4.22	1.00	1.61	0.50	0.50	0.50	0.25	0.25	0.25	0.25
6501	AUG 21	1000	37259	3.83	1.00	0.50	0.50	1.00	0.50	0.91	0.25	0.25	0.25
6503	AUG 21	1200	32786	5.43	1.00	0.50	0.50	2.65	0.50	1.40	0.25	0.75	1.75
6505	AUG 21	1400	39823	8.68	1.00	0.50	0.50	4.12	0.50	0.95	0.25	0.72	0.25
6507	AUG 21	1600	63519	1.66	1.00	0.50	1.00	1.00	0.50	0.85	0.25	0.90	0.25
6509	AUG 21	1800	91265	2.10	1.00	2.13	1.20	1.00	0.50	2.85	0.25	0.84	0.72
6511	AUG 21	2000	97266	3.88	1.00	4.19	2.20	2.04	0.50	6.04	0.25	1.34	0.25
6513	AUG 21	2200	36332	5.93	1.00	3.64	1.58	3.65	0.50	4.31	0.25	0.93	0.25
6515	AUG 21	2400	80846	4.72	1.00	2.60	1.46	1.31	0.50	1.53	0.25	0.50	0.25
6517	AUG 22	0200	23648	4.36	0.50	2.74	2.10	1.00	0.50	0.91	0.25	0.25	0.25
6519	AUG 22	0400	17948	3.40	1.00	2.30	2.10	1.00	0.50	0.63	0.25	0.25	0.25
6521	AUG 22	0600	14961	3.22	0.50	2.23	1.54	0.50	0.50	0.25	0.25	0.50	0.25
6523	AUG 22	0800	15752	3.07	1.00	2.11	1.09	0.50	0.50	0.25	0.25	0.50	0.25
6525	AUG 22	1000	23921	3.33	1.00	2.56	1.00	0.50	0.50	0.25	0.25	0.25	0.25
6527	AUG 22	1200	61316	3.86	0.50	2.30	1.00	0.50	0.50	1.25	0.25	0.50	0.25
6529	AUG 22	1400	31258	9.08	1.00	3.00	1.00	1.11	0.50	1.30	0.25	24.23	0.25
6531	AUG 22	1600	25912	20.19	1.00	3.19	1.00	2.48	0.50	1.24	0.25	2.99	0.25
6533	AUG 22	1800	31477	6.90	1.00	2.54	1.00	3.13	0.50	1.32	0.25	2.99	0.25
6535	AUG 22	2000	27931	6.61	1.00	2.46	1.00	3.05	0.50	1.29	0.25	4.71	0.25
6537	AUG 22	2200	24985	4.21	1.00	2.33	1.00	1.40	0.50	0.88	0.25	0.93	0.25
6539	AUG 22	2400	21875	7.45	1.00	2.24	1.00	2.55	0.50	0.72	0.25	0.77	2.02
6541	AUG 23	0200	17457	4.34	1.00	1.87	1.00	1.12	0.50	1.72	0.25	0.50	1.75
6543	AUG 23	0400	14511	3.81	1.00	2.20	1.00	1.19	0.50	0.81	0.25	0.67	0.25
6545	AUG 23	0600	15220	4.34	1.00	2.16	1.00	1.00	0.50	0.50	0.25	0.50	0.25
6547	AUG 23	0800	19639	2.77	0.50	1.69	0.50	0.50	0.50	0.50	0.25	0.25	0.25
6549	AUG 23	1000	29785	3.73	1.01	2.04	1.00	0.50	0.50	0.50	0.25	0.25	0.25

FILENAME : WELLVOLA.WK1

VOLATILE ORGANICS, WELLAND WPCP
PROJECT 431

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	CHLOROFORM		1.4-DICHLORO BENZENE		TRICHLORO ETHYLENE		TOLUENE		P&M - XYLENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
6551	AUG 23	1200	34095	4.12	1.00	2.47	1.00	1.84	0.50	0.79	0.25	0.50	3.36
6553	AUG 23	1400	38732	5.72	1.00	2.65	1.00	1.88	0.50	0.76	0.25	1.06	0.25
6555	AUG 23	1600	68135	1.50	0.50	1.27	0.50	1.00	0.50	0.25	0.25	0.50	0.25
6557	AUG 23	1800	63008	2.89	1.00	1.60	0.50	1.27	0.50	0.90	0.25	0.50	0.25
6559	AUG 23	2000	64862	2.78	1.00	2.89	1.00	1.00	0.50	0.77	0.25	0.50	0.25
6561	AUG 23	2200	60662	3.65	1.00	2.31	1.00	0.50	0.50	0.50	0.25	0.50	0.25
6563	AUG 23	2400	53897	3.87	1.00	2.33	1.00	1.00	0.50	1.35	0.25	0.83	0.25
6565	AUG 24	0200	54170	16.96	1.16	2.23	1.00	1.00	0.50	2.28	0.50	0.98	0.25
6567	AUG 24	0400	26021	3.56	1.00	2.64	1.00	1.00	0.50	1.58	0.25	0.25	0.25
6569	AUG 24	0600	17566	3.76	1.32	2.60	1.00	0.50	0.50	0.50	0.25	0.25	0.25
6571	AUG 24	0800	14729	2.71	1.18	2.01	1.00	0.50	0.50	0.25	0.25	0.25	0.25
6573	AUG 24	1000	35695	5.73	1.14	2.32	1.00	0.50	0.50	0.95	0.25	0.50	0.25
6575	AUG 24	1200	37641	5.02	1.00	2.73	0.50	1.10	0.50	1.21	0.25	0.50	0.25
6577	AUG 24	1400	30767	3.10	0.50	1.53	0.50	1.12	0.50	0.50	0.25	0.25	0.25
6579	AUG 24	1600	29022	5.60	1.00	2.26	0.50	3.40	0.50	16.80	0.25	0.50	0.25
6581	AUG 24	1800	27058	6.15	1.00	2.35	1.00	3.38	0.50	1.28	0.25	0.50	0.25
6583	AUG 24	2000	25967	5.10	1.00	2.21	1.00	1.70	0.50	0.92	0.25	0.25	0.25
6585	AUG 24	2200	25039	5.04	1.00	2.51	0.50	2.90	0.50	0.65	0.25	0.50	0.25
6587	AUG 24	2400	22366	3.74	1.00	2.20	1.00	1.64	0.50	0.50	0.25	0.25	0.25
6589	AUG 25	0200	16911	4.34	1.00	2.56	1.00	1.00	0.50	0.50	0.25	0.50	0.25
6591	AUG 25	0400	15002	3.61	1.00	2.06	1.00	0.50	0.50	0.50	0.25	0.25	0.25
6593	AUG 25	0600	15275	3.11	1.00	2.04	0.50	0.50	0.50	0.25	0.25	0.25	0.25
6595	AUG 25	0800	25258	2.91	0.50	2.14	0.50	0.50	0.50	0.25	0.25	0.25	0.25
6597	AUG 25	1000	35022	0.50	0.50	1.81	0.50	0.50	0.50	0.50	0.25	0.25	0.25
6599	AUG 25	1200	37968	16.02	1.00	2.60	0.50	1.82	0.50	0.81	0.25	0.50	0.25
6601	AUG 25	1400	34095	8.37	1.00	2.63	0.50	4.69	0.50	0.98	0.25	1.35	0.25
6603	AUG 25	1600	30004	13.47	1.00	2.72	0.50	1.00	0.50	1.41	0.25	0.71	0.25
6605	AUG 25	1800	28967	3.48	1.00	2.54	0.50	1.00	0.50	1.56	0.25	3.14	0.25
6607	AUG 25	2000	29294	3.39	0.50	1.74	0.50	1.00	0.50	0.60	0.25	0.50	0.25
6609	AUG 25	2200	25476	18.75	1.00	2.61	1.00	0.50	0.50	0.96	0.25	0.97	0.25
6611	AUG 25	2400	23294	11.13	0.50	2.94	0.50	0.50	0.50	3.23	0.25	0.81	0.25
6613	AUG 26	0200	17348	5.14	0.50	2.31	0.50	1.01	0.50	0.79	0.25	0.50	0.25
6615	AUG 26	0400	14184	3.79	0.50	2.00	0.50	0.50	0.50	0.66	0.25	0.25	0.25
6617	AUG 26	0600	15493	0.50	0.50	1.30	0.50	0.50	0.50	0.50	0.25	0.25	0.25
6619	AUG 26	0800	24767	0.50	0.50	1.86	0.50	0.50	0.50	0.50	0.25	0.25	0.25
6621	AUG 26	1000	34095	2.08	0.50	2.35	0.50	0.50	0.50	1.98	0.25	0.74	0.25
6623	AUG 26	1200	33413	10.42	0.50	2.50	0.50	0.50	0.50	0.73	0.25	0.75	0.25
6625	AUG 26	1400	30440	16.86	0.50	2.62	0.50	0.50	0.50	1.13	0.25	1.59	0.25
6627	AUG 26	1600	29176	5.10	1.63	1.74	0.50	0.50	0.50	0.50	0.25	10.28	0.25
6629	AUG 26	1800	75236	1.00	0.50	2.60	1.00	0.50	0.50	0.75	0.25	0.64	0.25
6631	AUG 26	2000	121160	2.17	0.50	2.46	1.00	0.50	0.50	3.62	0.25	0.95	0.25
6633	AUG 26	2200	105613	3.84	0.50	2.42	1.00	0.50	0.50	1.41	0.25	0.50	0.25
6635	AUG 26	2400	62844	0.50	0.50	2.60	1.00	0.50	0.50	0.50	0.25	2.23	0.25
6637	AUG 27	0200	58316	0.50	0.50	1.05	1.00	0.50	0.50	0.25	0.25	0.25	0.25
6639	AUG 27	0400	52679	3.10	0.50	2.14	1.00	0.50	0.50	0.91	0.66	0.78	0.25
6641	AUG 27	0600	49042	0.50	0.50	1.99	1.00	0.50	0.50	0.25	0.25	0.25	0.25
6643	AUG 27	0800	43042	0.50	0.50	1.82	0.50	0.50	0.50	0.25	0.25	0.25	0.25
6645	AUG 27	1000	32349	0.50	0.50	2.19	1.00	0.50	0.50	0.50	0.25	0.25	0.25
6647	AUG 27	1200	40567	0.50	0.50	1.73	1.00	0.50	0.50	0.25	0.25	0.25	0.25

VOLATILE ORGANICS. WELLAND WPCP
PROJECT 431

FILENAME : WELLVOLA.WK1

05/30/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	CHLOROFORM		1.4-DICHLORO BENZENE		TRICHLORO ETHYLENE		TOLUENE		P&M - XYLENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Num Data Points			99	99	99	99	99	99	99	99	99	99	99
Average			34974	5.07	0.86	2.18	0.85	1.30	0.50	1.21	0.26	1.17	0.37
Std. Deviation			20917	3.77	0.25	0.58	0.36	1.09	0.00	1.81	0.05	2.69	0.45
Minimum Value			14511	0.50	0.50	0.50	0.50	0.50	0.50	0.25	0.25	0.25	0.25
Maximum Value			121160	20.19	1.63	4.19	2.20	5.09	0.50	16.80	0.66	24.23	3.36

FILENAME : GALTCONC.WK1

GALT WPCP : ANALYTICAL DATA
PROJECT : 431

01/06/89

SAMP I.D.	DATE	TIME	FLOW (m^3/d)	UNITS : mg/L BOD IN	BOD OUT	TOC IN	TOC OUT	TKN IN	TKN OUT	NO3-N IN	NO3-N OUT	TSS IN	TSS OUT	UNITS : ug/L Cd IN	Cd OUT	Cr IN	Cr OUT	Cu IN	Cu OUT	Ni IN	Ni OUT	UNITS : mg/L P IN	P OUT	FILT. P IN	FILT. P OUT	UNITS : ug/L Pb IN	Pb OUT	Zn IN	Zn OUT	PHENOLICS (ug/LL) IN	PHENOLICS OUT	pH IN	pH OUT
0651	SEP 30	0800	0			23.4	14.3	30.0			9.9	110	30	1	1	30	19	96	25	20	30	3.14	1.12	2.57	0.32	10	5	155	76	11.2	1.0	7.77	7.32
0653	SEP 30	1000	49097			51.6	13.9					100	20	1	1	53	19	100	21	27	20	3.05	0.96	0.21	0.14	10	5	146	46	10.4	1.0	8.50	7.32
0655	SEP 30	1200	46200			39.2	12.2	15.2		7.9	1.0	100	20	3	1	59	20	135	30	64	26	4.19	1.14	2.06	0.21	10	5	167	49	1.0	11.2	8.07	7.42
0657	SEP 30	1400	54552			54.5	13.5					70	32	3	2	46	21	135	54	52	25	3.34	1.07	2.50	3.14	10	5	103	75	1.0	1.0	7.54	7.46
0659	SEP 30	1600	51934			50.7	14.6	14.0			1.1	70	23	1	2	29	21	116	55	27	30	3.29	1.14	2.64	0.20	10	5	101	77	34.4	1.0	7.61	7.45
0661	SEP 30	1800	50097			58.0	17.3					70	40	2	2	20	21	84	56	27	34	3.43	1.34	2.71	0.39	10	5	170	70	17.0	2.4	7.50	7.45
0663	SEP 30	2000	59571			65.7	16.1	17.6			13.5	100	36	1	2	31	22	100	56	25	33	3.70	1.42	2.86	0.39	10	5	200	86	21.4	1.0	8.10	7.29
0665	SEP 30	2200	50062			54.7	16.6					60	30	4	2	30	21	97	41	27	33	4.02	1.29	3.14	0.36	5	5	194	64	21.4	7.0	7.90	7.10
0667	SEP 30	2400	32131			82.2	17.4	17.2	14.2		10.4	110	40	2	2	22	21	80	45	16	32	3.06	1.37	1.71	0.36	5	5	56	71	12.0	4.0	8.05	7.15
0669	OCT 01	0200	41132			33.5	17.0					50	20	1	1	24	18	70	37	17	25	2.35	1.09	1.20	0.25	10	5	92	52	8.0	2.4	7.60	7.20
0671	OCT 01	0400	29076	20.0	15.0	18.3	17.4	9.2			14.6	30	20	2	2	23	19	49	40	18	29	2.01	1.09	1.64	0.36	5	5	81	51	2.0	2.0	7.60	7.29
0673	OCT 01	0600	31313			27.7	18.1					20	18	2	2	24	20	57	31	18	27	1.42	0.98	1.00	0.14	5	5	77	55	10.4	7.4	7.30	7.10
0675	OCT 01	0800	29458			25.5	16.2	30.0			1.1	50	20	2	1	29	20	93	30	21	24	3.52	0.86	2.64	0.14	5	5	122	40	20.1	7.0	7.20	7.05
0677	OCT 01	1000	45490			53.0	18.0					90	21	4	2	160	24	129	30	46	22	5.26	0.97	3.07	0.14	15	5	413	63	23.0	5.0	7.50	7.20
0679	OCT 01	1200	47515			52.5	14.7	20.6		13.4	1.0	210	24	8	2	63	23	103	32	5500	21	4.50	0.99	1.71	0.14	15	5	210	61	10.4	1.4	8.20	7.20
0681	OCT 01	1400	40606			65.2	14.9					80	33	8	2	116	25	162	55	64	141	4.05	1.36	2.93	0.20	10	5	210	60	10.6	1.6	7.75	7.53
0683	OCT 01	1600	48115			50.4	16.5	21.0			1.0	80	34	11	2	101	25	143	55	611	315	3.54	1.24	2.50	0.32	25	5	343	76	10.4	9.3	7.90	7.45
0685	OCT 01	1800	43151			50.6	10.7					130	35	4	3	51	27	103	60	97	324	4.28	1.40	3.07	0.36	15	5	104	70	23.0	2.4	7.60	7.40
0687	OCT 01	2000	53097			79.5	17.4	20.6			11.2	100	33	4	3	43	26	142	62	62	346	6.20	1.50	4.50	0.36	15	5	142	66	23.4	7.4	7.80	7.50
0689	OCT 01	2200	40096			69.0	17.6					80	34	3	3	40	27	95	51	51	308	3.82	1.57	2.86	0.36	5	5	158	69	21.4	2.8	7.70	7.50
0691	OCT 01	2400	43042			54.2	17.7	20.4			11.4	60	39	3	2	25	28	94	46	36	246	3.01	1.56	2.36	0.46	5	5	182	64	10.4	2.0	7.60	7.45
0693	OCT 02	0200	37150			39.0	18.6					60	30	1	2	20	26	59	44	30	213	3.55	1.39	2.20	0.39	10	5	94	76	25.6	7.4	8.35	7.40
0695	OCT 02	0400	28694			26.0	16.0	12.6		5.0	11.3	60	30	3	1	35	25	55	37	29	162	2.26	1.23	1.57	0.36	10	5	92	60	13.0	1.2	7.50	7.50
0697	OCT 02	0600	24930			22.9	16.7					60	40	3	2	41	26	74	37	26	145	1.66	1.23	1.07	0.28	15	5	91	56	10.2	1.4	7.50	7.52
0699	OCT 02	0800	29567			53.1	14.0	35.6			8.3	80	30	2	2	27	24	101	32	22	122	5.12	1.12	3.43	0.28	10	5	134	49	33.2	[illegible]	8.20	7.53
0701	OCT 02	1000	39114			86.1	14.3					123	30	4	2	69	27	130	47	27	105	5.75	1.30	2.28	0.18	50	5	101	57	37.0	[illegible]	8.35	7.43
0703	OCT 02	1200	44733			80.5	15.1	22.2	13.9		11.6	130	40	2	2	58	28	193	41	112	77	7.05	1.51	3.57	0.21	15	5	354	63	24.2	[illegible]	8.45	7.45
0705	OCT 02	1400	43096			69.0	17.1					140	25	4	2	66	27	203	46	47	72	5.51	1.71	3.64	0.39	25	5	222	106	47.4	[illegible]	7.55	7.53
0707	OCT 02	1600	43507			51.7	16.8	19.0			11.6	107	45	4	2	118	27	109	45	38	79	4.47	1.71	3.57	0.54	15	5	169	81	28.4	[illegible]	7.55	7.53
0709	OCT 02	1800	41070			65.9	17.1					139	38	25	2	1050	25	436	45	101	69	7.17	1.66	4.28	0.68	25	5	274	74	23.4	6.6	7.90	7.45
0711	OCT 02	2000	40933			75.7	17.7	23.4			13.2	190	42	5	2	197	28	342	49	122	59	5.23	1.00	1.86	0.54	15	5	259	74	19.1	1.4	8.70	7.53
0713	OCT 02	2200	43470			62.9	19.4					200	42	7	2	783	32	300	59	109	77	4.18	1.91	2.00	0.64	10	5	197	81	17.0	5.3	8.00	7.50
0715	OCT 02	2400	38405			41.2	18.9	19.4			11.9	110	37	4	2	424	35	221	71	43	103	4.15	1.70	2.14	0.36	5	5	106	95	13.6	6.9	8.40	7.50
0717	OCT 03	0200	30440			25.4	18.7					79	50	31	2	390	39	119	69	66	113	2.51	1.58	0.87	0.40	5	5	85	80	47.0	6.2	8.35	7.60
0719	OCT 03	0400	28785			20.3	17.0	11.5			11.3	100	25	3	3	32	39	66	69	19	123	2.04	1.29	0.80	0.29	5	5	70	95	13.2	6.6	8.30	7.60
0721	OCT 03	0600	23512	40.0	17.0	31.9	16.6					80	26	7	2	164	39	115	57	27	113	3.03	1.16	1.38	0.15	5	5	97	80	23.6	5.0	8.60	7.60
0723	OCT 03	0800	29785			43.6	16.0	32.2			9.5	100	29	5	3	50	41	100	49	21	101	4.43	1.10	2.91	0.22	5	5	136	56	25.6	5.0	7.70	7.55
0725	OCT 03	1030	44405			60.0	15.2					111	30	3	2	34	44	161	65	51	85	6.17	1.35	3.57	0.15	15	5	477	50	20.6	3.4	7.65	7.55
0727	OCT 03	1200	49479			56.7	16.7	21.6			12.1	120	47.1	3	3	55	63	117	69	37	55	6.19	1.73	4.76	0.36	35	5	195	68	25.4	2.4	7.55	7.55
0729	OCT 03	1430	37859			56.0	17.3					173.0	44	4	2	66	59	185	56	31	51	26.10	1.60	6.56	0.29	25	5	900	58	54.4	[illegible]	8.50	7.55
0731	OCT 03	1600	42005			70.7	16.8	18.7			12.5	120	45	9	3	56	51	120	63	36	49	4.56	1.88	2.91	0.40	25	5	205	67	32.9	[illegible]	7.65	7.53
0733	OCT 03	1800	42166			70.9	19.1					151	42	10	3	63	55	272	53	52	47	8.88	2.01	7.14	0.45	15	5	138	73	37.3	2.2	7.60	7.45
0735	OCT 03	2000	44296			70.5	19.7	23.0	15.3		11.7	145	50	9	3	53	41	121	67	30	45	6.82	2.27	3.38	0.44	15	10	199	92	19.6	[illegible]	8.45	7.45
0737	OCT 03	2200	40914			62.8	17.9					84.6	40	16	3	72	37	146	54	31	43	4.30	1.92	3.05	0.62	10	5	159	79	9.2	1.4	7.35	7.45
0739	OCT 03	2400	33004			65.1	17.6	19.1		11.2	11.6	98	43	6	2	40	34	102	62	26	39	3.35	1.96	2.04	0.59	5	5	137	124	81.6	4.2	7.80	7.55
0741	OCT 04	0200	27003			28.6	17.3					30	30	2	3	31	34	72	49	19	39	2.91	1.83	2.06	0.07	5	5	84	115	34.0	6.6	7.30	7.60
0743	OCT 04	0400	21857			30.4	16.7	12.4			13.9	45	36	2	2	25	32	63	44	16	36	1.90	1.55	0.51	0.41	5	5	71	89	18.0	5.3	7.80	7.60
0745	OCT 04	0600	19911			17.0	15.5					26	30	1	2	22	30	51	41	16	34	1.37	1.32	1.09	0.41	5	5	79	56	12.0	[illegible]	7.45	7.53
0747	OCT 04	0800	18439			19.9	15.0	24.0		12.5	10.5	43	21	3	2	41	39	73	43	23	33	2.50	1.24	2.01	0.17	5	5	83	73	15.2	[illegible]	7.50	7.45

FILENAME : GALTCONC.WK1

GALT WPCP : ANALYTICAL DATA
PROJECT : 431

01/06/89

SAMP I.D.	DATE	TIME	FLOW (m^3/d)	BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		PHENOLICS (ug/LL)		pH	
				UNITS : mg/L										UNITS : ug/L								UNITS : mg/L				UNITS : ug/L							
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT			IN	OUT
6749	OCT 04	1000	27494			61.7	15.7					116	25	4	2	34	26	133	37	20	29	6.26	1.09	4.55	0.14	5	5	165	55	20.4	2.4	7.55	7.35
6751	OCT 04	1200	37750			49.8	14.5	28.0			9.9	162	35	4	3	35	32	157	42	58	31	6.50	1.34	3.74	0.17	20	5	237	60	21.5	4.0	7.50	7.40
6753	OCT 04	1400	40859			51.2	14.1					197	49	6	2	53	37	166	59	47	29	4.93	1.08	3.22	0.17	45	5	259	74	13.6	8.0	7.40	7.40
6755	OCT 04	1600	47624			42.2	15.9	19.8	17.8		14.4	87	50	4	3	43	37	128	54	29	33	4.62	2.11	2.91	0.31	20	5	170	76	18.0	10.6	7.40	7.40
6757	OCT 04	1800	38332			45.9	13.5					72	38	9	3	70	34	142	56	36	34	3.45	1.94	2.00	0.24	10	5	133	73	23.0	5.0	7.40	7.40
6759	OCT 04	2000	35568	105.0	22.0	52.1	14.0	28.6			13.2	96	47	1	2	26	33	127	46	18	31	3.94	1.75	2.91	0.21	5	5	120	69	19.0	2.4	7.60	7.45
6761	OCT 04	2200	33004			40.5	12.2					68	39	2	2	22	35	95	41	44	31	3.25	1.65	2.66	0.24	5	5	90	81	18.4	2.4	7.55	7.40
6763	OCT 04	2400	26621			37.4	12.9	21.0			11.7	42.1	39	1	2	28	30	76	41	17	28	3.56	1.51	3.36	0.21	10	5	85	79	26.6	4.0	7.60	7.45
6765	OCT 05	0200	26105			26.4	13.0					29	28	1	2	19	29	55	40	13	28	2.86	1.39	2.38	0.14	10	5	90	101	23.0	5.0	7.50	7.50
6767	OCT 05	0400	20093			18.0	12.3	15.2	15.9		12.6	18	31	2	2	22	26	46	32	17	25	1.84	1.28	1.68	0.14	5	5	83	75	15.4	2.4	7.55	7.60
6769	OCT 05	0600	19002			17.8	11.7					11	25	1	2	22	27	47	34	17	27	1.38	1.18	1.12	0.07	5	5	129	86	7.2	2.6	7.50	7.60
6771	OCT 05	0800	18111			13.3	11.0	12.1			12.9	30	30	2	2	20	27	57	31	19	25	1.44	1.08	0.98	0.03	10	5	164	49	9.8	2.0	7.40	7.45
6773	OCT 05	1000	24985			42.2	10.9					86	28	1	1	22	23	111	34	16	20	4.65	0.97	3.50	0.10	10	5	145	43	21.4	3.2	7.70	7.50
6775	OCT 05	1200	36441			51.8	11.8	31.6			13.0	123	31	1	2	27	30	133	34	86	25	6.29	1.18	5.18	0.14	15	5	232	45	27.4	2.0	7.65	7.55
6777	OCT 05	1400	40036	135.0	20.0	53.6	11.9					125	40	2	2	23	32	113	51	19	25	4.71	1.52	3.57	0.14	10	5	152	55	11.0	3.2	7.50	7.55
6779	OCT 05	1600	36160			52.2	13.4	18.9			17.1	118	32	2	2	23	28	107	47	19	28	4.47	1.50	2.91	0.21	10	5	132	55	22.2	2.6	7.45	7.50
6781	OCT 05	1800	33713			52.9	12.3					68	31	2	2	22	28	108	40	16	28	3.82	1.59	3.01	0.14	20	5	131	52	20.4	1.0	7.50	7.50
6783	OCT 05	2000	35241			53.7	13.6	20.0		12.6	15.3	90	31	2	2	24	29	103	44	16	27	4.33	1.40	3.50	0.20	10	5	101	50	22.0	1.0	7.55	7.53
6785	OCT 05	2200	35186			41.8	14.0					67	31	2	2	29	32	138	53	22	32	3.95	1.47	3.13	0.20	20	15	135	81	21.4	5.0	7.65	7.53
6787	OCT 05	2400	34477			36.7	13.3	20.0			15.0	35	30	2	2	29	29	105	44	21	26	3.08	1.40	2.40	0.20	10	10	135	69	41.2	1.0	7.59	7.52
6789	OCT 06	0200	24276			18.6	14.0					15	28	2	1	26	28	68	37	20	25	1.71	1.27	1.40	0.22	15	5	125	91	12.0	5.0	7.35	7.52
6791	OCT 06	0400	20893			17.6	13.0	9.4			15.0	16	27	2	2	34	27	48	38	24	28	1.39	1.13	1.00	0.23	10	10	72	84	9.6	3.0	7.40	7.52
6793	OCT 06	0600	21003			22.6	13.6					23	23	2	2	178	27	96	37	370	30	1.21	1.09	3.73	0.23	15	5	107	66	14.6	5.8	7.55	7.55
6795	OCT 06	0800	30058			41.4	13.8	33.0	15.0		13.7	32	24	2	2	37	29	150	42	26	24	6.07	1.22	2.67	0.13	15	15	161	91	21.4	4.0	[illegible]	[illegible]
6797	OCT 06	1000	42114			47.4	13.6					163	34	7	2	70	28	171	52	60	19	5.66	1.23	3.60	0.13	25	5	376	75	25.0	5.2	[illegible]	7.60
6799	OCT 06	1200	42169			68.2	14.6	20.0			14.2	140	29	5	2	145	30	201	45	93	18	5.39	1.24	3.45	0.20	40	5	292	56	39.0	[illegible]	[illegible]	7.53
6801	OCT 06	1400	42605			72.1	17.7					130	39	9	2	259	35	156	53	46	31	4.76	1.67	2.83	0.30	25	10	336	88	34.4	[illegible]	[illegible]	[illegible]
6803	OCT 06	1600	42714			64.0	18.9	20.2			14.7	120	39	60	2	673	31	217	57	76	29	4.24	1.76	2.83	0.40	25	5	390	92	49.4	[illegible]	7.50	[illegible]
6805	OCT 06	1800	38241			73.1	18.0					98	40	3	2	117	42	122	49	32	31	4.19	1.68	2.83	0.43	15	5	257	92	40.4	2.5	[illegible]	7.55
6807	OCT 06	2000	30350			81.5	18.3	21.4		12.7	12.8	170	38	2	3	75	39	124	58	27	34	5.59	1.79	3.69	0.47	20	5	201	114	21.4	[illegible]	8.62	7.63
6809	OCT 06	2200	30732			72.1	19.5					88	37	1	2	38	34	98	50	18	31	3.78	1.68	3.17	0.63	5	5	226	312	17.0	3.4	[illegible]	7.50
6811	OCT 06	2400	30023			79.6	19.6	19.0			13.5	110	40	1	3	42	35	205	41	32	31	4.77	1.69	1.87	0.40	5	5	155	96	24.0	3.2	9.60	7.65
6813	OCT 07	0200	30713			54.0	19.4					50	36	1	2	74	33	78	38	14	27	4.35	1.47	3.23	0.50	5	5	211	63	18.0	6.0	8.90	7.65
6815	OCT 07	0400	25140			39.3	18.6	11.4			12.9	120	35	2	11	82	30	149	32	41	27	2.47	1.22	0.27	0.31	15	5	223	109	6.6	6.0	7.59	7.73
6817	OCT 07	0600	24712			30.6	18.5					570	32	13	2	199	31	619	32	79	29	13.60	1.19	0.14	0.27	70	5	715	193	8.4	3.2	7.20	7.55
6819	OCT 07	0800	34360			33.0	17.9	43.2			11.2	230	30	5	3	76	38	277	37	40	31	7.02	1.15	2.11	0.17	35	5	360	99	26.2	4.0	8.60	7.55
6821	OCT 07	1000	38950	110.0	19.0	57.8	17.4					160	32	3	2	87	28	129	39	98	25	6.72	1.09	2.99	0.20	15	5	369	191	20.0	3.4	7.25	7.50
6823	OCT 07	1200	46507			77.2	18.2	19.8			14.4	188	40	2	2	53	30	115	45	117	27	7.91	1.49	3.88	0.20	5	5	271	96	29.2	4.6	7.75	7.50
6825	OCT 07	1400	37259			77.8	20.3					139	42	3	2	44	35	127	48	105	46	4.86	1.52	2.99	0.17	24	5	219	98	50.0	4.6	7.50	7.55
6827	OCT 07	1600	39168			59.8	19.5	17.5	17.9		15.0	95	45	2	3	36	36	150	53	41	117	5.01	1.59	3.41	0.27	15	5	308	84	35.0	5.0	8.75	7.55
6829	OCT 07	1800	39160			87.0	21.3					147	41	25	3	77	31	333	51	98	120	5.35	1.58	3.76	0.27	10	5	364	77	36.4	5.0	7.60	7.53
6831	OCT 07	2000	30706			91.5	22.2	22.4		12.2	13.0	174	51	32	3	68	32	331	55	89	108	4.40	1.74	3.06	0.20	30	5	349	96	29.2	6.6	7.65	7.60
6833	OCT 07	2200	42714			78.5	22.4					142	48	81	4	88	38	666	55	116	106	4.72	1.85	3.26	0.37	20	5	240	240	10.8	3.2	7.95	7.45
6835	OCT 07	2400	38560			95.2	24.2	19.4			12.9	112	37	5	5	83	40	354	77	59	108	3.21	1.62	1.93	0.41	10	5	125	150	22.2	5.8	7.55	7.55
6837	OCT 08	0200	30050			57.0	21.5					78	35	6	5	75	28	221	85	81	105	2.13	1.39	1.09	0.34	5	5	201	103	9.0	1.0	7.60	7.52
6839	OCT 08	0400	26021			49.8	22.4	11.3			12.2	108	34	20	5	252	35	112	80	41	100	2.60	1.26	2.45	0.20	5	5	119	132	49.0	4.0	7.50	7.52
6841	OCT 08	0600	24650			43.1	22.3					53	34	20	5	172	34	117	76	38	98	1.27	1.06	0.47	0.13	5	5	145	104	23.4	0.0	8.10	7.45
6843	OCT 08	0800	32513	40.0	5.0	39.3	19.1	33.8		18.4	10.9	88	25	7	4	114	38	110	70	35	93	4.79	0.92	2.79	0.17	5	5	218	56	25.0	13.6	8.30	7.32
6845	OCT 08	1000	39987			54.2	19.9					150	26.5	6	4	88	32	129	58	30	73	4.59	0.97	2.79	0.17	20	5	203	68	26.6	4.0		

FILENAME : GALTCONC.WK1

GALT WPCP : ANALYTICAL DATA
PROJECT : 431

01/06/89

SAMP DATE TIME	FLOW	UNITS : mg/L										UNITS : ug/L								UNITS : mg/L				UNITS : ug/L				PHENOLICS		pH	
		BOD		TOC		TKN		NH3-N		TSS		Cd		Cr		Cu		Ni		P		FILT. P		Pb		Zn		(ug/LL)			
I.D.	(m^3/d)	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT			IN	OUT
0847 OCT 08 1200	42005			73.4	20.1	21.8	15.7		12.1	120	37	4	5	71	60	223	70	201	61	4.09	1.34	1.70	0.17	10	5	173	75	30.4	9.7		
Num Data Points	99	8	8	99	99	50	8	9	50	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	97	97
Average	36327	78.50	16.33	50.96	18.55	20.06	15.60	11.92	11.37	102.00	34.16	6.10	2.42	92.84	31.01	146.31	49.17	110.75	66.56	4.43	1.42	2.63	0.29	13.08	5.40	190.00	83.17	23.59	4.32	7.84	7.47
Std. Deviation	10030	46.12	6.06	19.10	2.81	7.09	1.25	3.54	3.80	66.91	7.96	9.89	1.23	151.17	8.13	102.41	13.67	552.53	60.17	2.08	0.30	1.22	0.15	10.79	1.70	126.36	40.74	12.84	2.60	0.40	0.13
Minimum Value	0	20.00	5.00	13.30	10.90	9.20	13.90	5.00	1.00	10.00	18.00	1.00	1.00	19.00	10.00	46.00	21.00	13.00	18.00	1.21	0.06	0.14	0.03	5.00	5.00	71.00	43.00	1.00	1.00	7.20	7.05
Maximum Value	50571	135.00	22.00	95.20	24.20	43.20	17.60	18.40	17.10	570.00	51.00	61.00	11.00	1050.00	63.00	686.00	85.00	5500.00	346.00	26.10	2.11	7.14	0.87	70.00	15.00	900.00	312.00	81.60	13.60	9.60	7.80

VOLATILE ORGANICS (ppb), GALT WPCP
PROJECT 431

FILENAME : GALTVOLA.WK1

12/19/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	CHLOROFORM IN	CHLOROFORM OUT	1,1,1-TRICHLOROETHANE IN	1,1,1-TRICHLOROETHANE OUT	BENZENE IN	BENZENE OUT	TRICHLOROETHYLENE IN	TRICHLOROETHYLENE OUT	TOLUENE IN	TOLUENE OUT	TETRACHLOROETHYLENE IN	TETRACHLOROETHYLENE OUT	ETHYL BENZENE IN	ETHYL BENZENE OUT	p & m - XYLENE IN	p & m - XYLENE OUT	1,4-DICHLOROBENZENE IN	1,4-DICHLOROBENZENE OUT	O-XYLENE IN	O-XYLENE OUT	1,2-DICHLORO BENZENE IN	1,2-DICHLORO BENZENE OUT
6651	SEP 30	0800	0	0.50	0.50	4.15	1.99	0.05	0.25	3.19	1.00	4.09	0.50	4.45	13.02	0.62	0.25	2.09	0.50	4.25	1.59	0.00	0.50	0.50	0.50
6653	SEP 30	1000	40097	2.01	0.50	3.56	2.39	0.97	0.25	3.59	1.00	0.05	0.25	12.23	0.75	210.90	0.56	1146.77	1.30	4.51	2.43	70.10	0.50	1.49	0.50
6655	SEP 30	1200	40260	3.20	0.50	5.63	2.00	1.66	0.25	4.20	1.00	0.55	0.25	10.35	5.02	30.70	1.29	190.29	0.51	5.34	2.00	10.65	0.50	1.00	0.50
6657	SEP 30	1400	54552	2.75	1.00	5.99	4.60	1.06	0.25	4.10	1.00	5.24	0.25	40.72	5.91	6.24	4.91	31.47	5.30	4.51	1.00	5.34	3.62	0.50	1.00
6659	SEP 30	1600	51934	3.05	3.05	7.32	4.93	1.40	0.50	4.42	1.00	86.25	0.50	159.19	12.07	4.72	3.15	25.43	1.52	4.20	1.22	15.55	1.19	7.50	1.22
6661	SEP 30	1800	50097	2.09	2.09	4.00	1.96	0.96	0.25	4.05	1.00	9.54	0.25	434.27	20.02	3.34	1.52	15.44	2.79	5.32	1.00	9.37	0.09	3.50	0.50
6663	SEP 30	2000	59571	2.76	2.76	5.00	4.30	1.01	0.25	4.06	1.20	7.71	0.25	140.10	120.07	2.26	1.30	10.24	0.96	6.37	4.61	3.04	1.15	4.69	4.61
6665	SEP 30	2200	58062	3.60	3.60	3.57	4.76	0.25	0.92	1.32	4.60	0.25	4.55	119.30	43.75	0.92	1.90	2.40	9.50	2.13	1.57	1.00	4.12	4.43	1.57
6667	SEP 30	2400	32131	1.04	1.04	5.10	2.56	0.99	0.25	5.00	1.29	3.70	0.25	14.02	80.00	10.63	0.71	61.32	2.01	4.24	3.39	20.75	0.91	1.00	3.39
6669	OCT 01	0200	41132	1.00	1.00	4.00	1.50	0.90	0.25	4.74	1.00	3.52	0.25	12.20	31.11	3.14	0.50	10.23	1.24	3.40	1.13	5.33	0.64	1.00	1.42
6671	OCT 01	0400	29070	0.50	1.00	3.70	2.30	0.61	0.25	3.42	1.00	1.04	0.25	5.15	35.03	0.59	0.50	3.19	1.60	2.23	1.77	0.93	0.90	1.00	1.65
6673	OCT 01	0600	31313	1.00	1.00	4.75	1.71	1.00	0.25	4.90	1.00	3.07	0.25	7.30	20.23	1.04	0.25	5.60	0.50	3.32	1.49	1.50	0.25	1.00	1.00
6675	OCT 01	0800	29450	2.10	1.00	5.20	1.93	1.05	0.25	5.92	1.00	3.29	0.25	0.32	11.72	0.97	0.25	5.00	0.25	5.10	1.33	2.35	0.25	1.00	1.00
6677	OCT 01	1000	45496	2.00	1.00	4.99	1.59	0.07	0.25	4.90	1.00	4.21	0.25	25.62	6.02	1.36	0.25	6.51	0.25	6.20	1.10	3.14	0.25	1.00	1.00
6679	OCT 01	1200	47515	10.00	1.00	5.35	1.52	0.00	0.25	4.36	1.00	4.65	0.25	22.56	2.76	2.50	0.25	13.62	0.25	4.10	1.00	9.47	0.25	1.00	0.50
6681	OCT 01	1400	40606	3.93	1.11	3.46	2.64	0.50	0.25	2.54	1.00	4.54	0.25	0.92	4.51	1.07	0.25	5.31	0.25	2.00	1.40	3.59	0.25	1.00	0.50
6683	OCT 01	1600	40115	5.00	1.06	9.06	2.52	1.09	0.25	6.69	1.00	7.59	0.25	23.32	4.04	4.29	0.73	31.37	3.49	4.40	1.76	10.44	0.50	19.50	1.00
6685	OCT 01	1800	43151	5.13	2.02	0.02	2.32	1.01	0.25	6.34	1.00	0.40	0.25	423.73	4.39	5.12	0.25	29.24	0.50	4.90	1.70	10.51	0.50	5.94	1.90
6687	OCT 01	2000	53097	4.36	1.52	5.73	2.65	0.01	0.25	3.97	1.00	5.52	0.25	251.75	11.90	2.01	0.25	11.02	0.25	5.64	1.54	7.04	0.25	3.17	1.90
6689	OCT 01	2200	40096	3.90	1.00	5.07	2.51	0.09	0.25	3.94	1.00	4.91	0.25	107.25	10.04	14.07	0.25	03.95	0.25	4.00	1.23	26.17	0.25	1.13	1.30
6691	OCT 01	2400	43042	5.33	1.40	4.42	2.07	0.57	0.25	3.29	1.12	2.55	0.25	7.32	45.74	1.36	0.25	0.57	0.25	3.60	1.73	2.79	0.50	3.55	1.10
6693	OCT 02	0200	37150	2.00	1.26	5.09	2.64	0.09	0.25	3.93	1.12	3.22	0.25	5.74	35.60	1.13	0.25	0.65	0.25	3.71	1.72	3.45	0.25	1.25	1.30
6695	OCT 02	0400	20694	1.16	1.00	5.56	2.25	1.00	0.25	5.23	1.00	3.40	3.25	4.33	17.63	0.92	0.25	5.11	0.25	3.33	1.36	2.07	0.25	1.56	1.30
6697	OCT 02	0600	24930	1.12	1.00	5.63	1.07	1.10	0.25	6.00	1.00	1.11	0.25	4.13	11.62	0.60	0.25	3.57	0.50	3.90	1.46	1.10	0.25	1.00	1.30
6699	OCT 02	0800	29567	1.00	0.50	4.28	1.00	1.21	0.25	3.07	0.50	2.76	0.25	1.96	3.29	156.45	0.25	931.31	2.62	3.55	1.90	275.73	9.85	1.00	0.50
6701	OCT 02	1000	39114	2.27	1.00	5.67	1.54	1.06	0.25	4.44	1.00	3.76	0.25	22.37	5.07	50.06	0.25	302.63	0.25	5.46	1.14	72.77	0.25	1.00	0.50
6703	OCT 02	1200	44733	3.76	1.00	5.00	2.60	0.09	0.25	3.70	1.00	5.90	0.25	101.70	3.14	3.77	0.25	21.97	0.25	3.90	1.23	0.71	0.25	2.36	1.30
6705	OCT 02	1400	43696	2.05	1.00	6.10	2.44	0.95	0.25	4.04	1.00	5.74	0.25	4.04	3.49	4.40	0.25	41.15	0.25	7.60	1.34	6.79	0.50	22.54	1.30
6707	OCT 02	1600	43507	5.16	1.00	6.43	3.67	1.00	0.25	4.57	1.00	19.20	0.50	4.57	7.64	3.44	0.25	21.40	0.25	4.40	1.24	16.32	0.25	1.95	1.30
6709	OCT 02	1800	41070	1.02	1.00	4.79	1.95	0.61	0.25	3.10	1.00	6.22	0.25	3.10	3.53	1.41	0.25	7.90	0.25	2.67	1.02	2.55	0.25	1.00	1.30
6711	OCT 02	2000	40933	2.06	1.00	4.93	2.03	0.75	0.25	3.61	1.04	4.44	0.25	3.61	6.70	1.25	0.25	6.32	0.25	4.22	1.60	4.56	0.25	1.06	1.31
6713	OCT 02	2200	43470	2.21	1.00	5.66	2.99	0.91	0.25	4.52	1.09	4.93	0.25	4.52	21.06	1.29	0.25	7.09	0.25	5.30	1.54	2.31	0.25	1.00	1.30
6715	OCT 02	2400	30405	1.71	1.00	5.53	2.55	0.05	0.25	4.55	1.01	6.54	0.25	4.55	23.61	1.10	0.25	6.27	0.25	4.75	1.40	2.11	0.25	2.71	1.30
6717	OCT 03	0200	30440	1.25	1.00	6.09	1.52	0.93	0.25	4.90	0.50	2.91	0.25	4.71	12.34	0.66	0.25	4.26	0.25	3.26	1.12	1.42	0.25	0.50	0.50
6719	OCT 03	0400	26705	0.50	1.00	3.93	2.40	0.53	0.25	3.04	0.50	1.40	0.25	1.62	13.13	0.50	0.25	1.01	0.25	2.03	1.27	0.59	0.25	0.50	0.50
6721	OCT 03	0600	23512	1.13	1.00	5.02	1.99	1.07	0.25	5.00	0.50	3.04	0.25	13.13	0.09	0.56	0.25	3.66	0.25	3.27	1.29	1.00	0.25	0.50	0.50
6723	OCT 03	0800	29705	1.44	1.00	5.74	2.02	0.75	0.25	5.19	0.50	2.30	0.25	0.09	5.39	0.50	0.25	3.72	0.25	4.07	1.12	4.14	0.25	0.50	0.50
6725	OCT 03	1000	44405	1.95	1.00	6.50	2.17	0.75	0.25	4.79	0.50	3.35	0.25	5.39	3.17	2.62	0.25	12.04	0.25	5.96	1.07	3.03	0.25	3.17	0.50
6727	OCT 03	1200	49479	7.20	1.00	6.20	1.29	0.07	0.25	4.16	0.50	4.05	0.25	3.17	1.00	1.04	0.25	5.55	0.25	3.60	1.00	2.06	0.25	6.02	0.50
6729	OCT 03	1400	37059	1.47	1.00	4.41	2.30	2.04	0.25	3.06	1.00	6.50	0.25	11.27	2.11	1.92	0.25	11.14	0.25	3.57	1.26	9.47	0.25	2.71	1.30
6731	OCT 03	1600	42005	4.31	1.00	5.01	3.24	1.43	0.25	4.07	1.00	6.13	0.25	79.20	4.43	1.74	0.25	9.02	0.25	4.50	1.26	4.13	0.25	1.00	1.30
6733	OCT 03	1800	42169	6.02	1.00	7.27	2.93	0.91	0.25	4.79	1.15	6.39	0.25	19.33	14.56	12.46	0.25	73.05	0.60	4.82	1.03	22.64	0.50	1.09	1.30
6735	OCT 03	2000	44296	4.07	1.00	7.52	2.61	0.79	0.25	4.64	1.05	4.37	0.25	200.30	14.30	2.30	0.50	11.03	0.79	4.02	1.60	4.14	0.01	1.00	1.30
6737	OCT 03	2200	40914	16.14	1.00	6.92	1.07	0.07	0.25	4.06	1.00	3.75	0.25	10.50	0.31	1.10	0.25	6.29	0.93	4.90	1.39	1.96	0.60	1.00	1.30
6739	OCT 03	2400	33004	14.09	1.16	5.57	2.10	0.93	0.25	4.35	1.03	3.46	0.25	4.10	12.60	13.42	0.50	02.05	1.55	3.97	1.62	30.29	1.07	0.50	1.30
6741	OCT 04	0200	27003	1.11	1.02	5.76	2.20	1.09	0.25	5.23	1.00	3.54	0.25	3.04	7.17	3.42	0.50	17.17	0.76	4.04	1.26	5.21	0.02	1.00	0.50
6743	OCT 04	0400	21657	1.02	1.00	5.74	2.04	1.04	0.25	5.09	1.00	3.16	0.25	3.30	5.56	0.92	0.50	4.04	0.50	3.42	1.20	1.73	0.50	0.50	0.50
6745	OCT 04	0600	19911	1.00	1.00	5.00	1.94	0.05	0.25	5.20	1.00	2.35	0.25	2.06	2.47	0.60	0.25	3.55	0.25	3.25	1.00	1.33	0.25	0.50	0.50
6747	OCT 04	0800	18439	1.00	1.00	4.50	2.10	0.67	0.25	3.04	1.00	1.54	0.25	1.54	3.00	0.50	0.25	1.43	2.50	2.40	1.04	0.54	0.25	0.50	0.50

VOLATILE ORGANICS (ppb), GALT WPCP
PROJECT 431

FILENAME : GALTVOLA.WE1

12/19/88

SAMPLE I.D.	DATE	TIME	FLOW (m^3/d)	CHLOROFORM		1,1,1-TRICHLOROETHANE.		BENZENE		TRICHLOROETHYLENE		TOLUENE		TETRACHLOROETHYLENE		ETHYL BENZENE		p & m - XYLENE		1,4-DICHLOROBENZENE		O-XYLENE		1,2-DICHLORO BENZENE	
				IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
0749	OCT 04	1000	27494	3.14	1.00	6.01	3.29	0.90	0.25	5.20	1.00	2.79	0.25	6.16	2.10	0.66	0.25	3.04	0.25	4.96	1.00	1.42	0.25	0.50	0.50
0751	OCT 04	1200	37750	5.43	1.00	5.72	2.05	0.74	0.25	4.46	1.00	3.64	0.25	14.03	2.06	1.26	0.25	5.09	0.25	7.80	1.03	4.23	0.50	0.50	0.50
0753	OCT 04	1400	40859	9.09	1.00	5.55	2.01	0.50	0.25	4.36	1.00	121.71	0.25	17.57	1.07	3.07	0.25	10.13	0.25	5.67	1.33	10.50	0.25	0.50	0.50
0755	OCT 04	1600	47624	2.96	1.20	4.00	3.11	0.57	0.25	4.05	1.00	90.33	0.5	7.01	1.23	7.02	0.25	50.01	0.50	4.70	1.00	17.40	0.25	0.50	0.50
0757	OCT 04	1800	30932	5.03	1.19	5.00	3.41	0.85	0.25	5.20	1.00	53.00	0.50	6.76	2.10	1.27	0.25	6.24	0.25	5.01	1.56	0.50	0.25	0.50	0.50
0759	OCT 04	2000	35560	4.54	1.07	5.95	2.50	0.80	0.25	4.35	1.00	40.79	0.25	5.10	2.03	1.00	0.25	7.06	0.25	4.44	1.50	2.02	0.25	0.50	0.50
0761	OCT 04	2200	33004	2.40	1.11	5.55	3.00	0.94	0.25	4.52	1.00	110.01	0.53	7.20	2.01	1.04	0.25	8.03	0.25	4.70	1.47	1.90	0.25	0.50	0.50
0763	OCT 04	2400	20621	1.04	1.00	5.70	2.75	1.01	0.25	4.00	1.00	50.39	0.25	3.40	1.72	0.96	0.25	4.27	0.25	4.30	1.54	3.60	0.25	0.50	0.50
0765	OCT 05	0200	28105	1.90	1.00	2.50	2.14	0.50	0.25	2.12	1.00	7.99	0.50	1.00	1.46	0.25	0.25	0.90	0.25	1.04	1.40	0.25	0.50	0.50	0.50
0767	OCT 05	0400	20893	1.00	1.00	5.94	1.90	0.80	0.25	5.10	1.00	5.32	0.25	2.42	1.00	0.50	0.25	2.30	0.25	3.60	1.33	0.94	0.25	0.50	0.50
0769	OCT 05	0600	19002	1.00	1.00	6.01	1.71	1.04	0.25	5.56	1.00	5.32	0.25	2.20	1.00	0.50	0.25	1.42	0.25	3.44	1.27	1.06	0.25	0.50	0.50
0771	OCT 05	0800	18111	1.00	1.00	5.51	1.04	0.85	0.25	5.20	1.00	2.71	0.25	2.00	1.00	0.50	0.25	2.01	0.25	3.23	1.23	0.70	0.25	0.50	0.50
0773	OCT 05	1000	24905	1.21	0.50	6.03	1.00	0.91	0.25	5.37	0.50	3.56	0.25	1.14	1.00	0.50	0.25	2.75	0.25	5.35	1.00	0.94	0.25	0.50	0.50
0775	OCT 05	1200	30441	1.00	0.50	1.00	2.10	0.25	0.25	1.00	0.50	0.25	0.25	0.50	1.00	0.25	0.25	0.25	0.25	1.29	1.03	0.25	0.25	0.50	0.50
0777	OCT 05	1400	40036	6.39	1.00	5.38	2.23	0.50	0.25	4.45	1.00	0.25	0.25	4.06	1.00	0.00	0.25	2.03	0.25	5.20	1.35	2.63	0.25	0.50	0.50
0779	OCT 05	1600	36160	4.44	1.00	5.01	2.35	0.50	0.25	4.00	1.00	1.41	0.25	4.74	1.06	0.82	0.25	2.72	0.25	4.60	1.37	1.57	0.25	0.50	0.50
0781	OCT 05	1800	33713	4.71	1.00	5.44	2.37	0.25	0.25	4.29	1.00	2.27	0.25	0.35	1.00	1.06	0.25	4.19	0.25	4.24	1.52	1.40	0.25	0.50	0.50
0783	OCT 05	2000	35241	1.60	1.00	5.04	1.51	0.50	0.25	4.43	1.00	0.83	0.25	1.46	0.50	0.50	0.25	0.92	0.25	2.51	1.00	0.56	0.25	0.50	0.50
0785	OCT 05	2200	35106	1.00	1.00	6.15	2.38	0.68	0.25	5.53	1.00	3.27	1.11	2.17	0.50	0.50	0.25	2.45	0.25	5.12	1.43	0.70	0.25	0.50	0.50
0787	OCT 05	2400	34477	5.56	1.00	5.60	2.04	0.71	0.25	4.21	1.00	3.54	0.25	4.06	1.07	0.25	0.25	3.10	0.25	4.75	1.61	1.21	0.25	0.50	0.50
0789	OCT 06	0200	24276	5.20	1.00	5.40	2.07	0.66	0.25	4.49	1.00	3.56	0.25	4.39	1.07	0.56	0.25	3.20	0.25	5.01	1.60	1.50	0.25	0.50	0.50
0791	OCT 06	0400	20893	4.38	0.50	5.56	1.90	0.80	0.25	5.07	1.00	24.87	0.25	19.36	1.00	1.49	0.25	7.39	0.25	5.10	1.26	2.41	0.25	0.50	0.50
0793	OCT 06	0600	21003	1.00	0.50	2.67	2.77	0.25	0.25	2.01	1.00	0.07	0.25	1.00	1.00	0.25	0.25	0.70	0.25	1.20	1.20	0.25	0.25	0.50	0.50
0795	OCT 06	0800	30050	1.00	0.50	4.93	1.24	0.62	0.25	4.90	1.00	5.10	0.25	1.41	1.00	0.50	0.25	1.60	0.25	4.26	1.24	0.60	0.25	0.50	0.50
0797	OCT 06	1000	42114	1.51	0.50	5.70	1.44	0.56	0.25	4.39	1.00	4.62	0.25	0.90	0.50	0.25	0.25	0.90	0.25	4.22	1.05	13.04	0.25	0.50	0.50
0799	OCT 06	1200	42169	2.00	0.50	4.90	1.50	0.54	0.25	4.09	1.00	3.22	0.25	5.15	1.00	1.27	0.25	4.43	0.25	6.52	1.27	6.22	0.25	1.50	0.50
0801	OCT 06	1400	42005	2.70	0.50	5.54	2.50	0.53	0.25	4.06	1.00	2.90	0.25	6.24	1.00	0.95	0.25	4.36	0.25	4.79	1.03	1.62	0.25	12.79	0.50
0803	OCT 06	1600	42714	1.32	1.00	3.49	2.45	0.50	0.25	3.10	1.13	2.27	0.25	4.70	1.11	0.25	0.25	7.90	0.50	3.31	1.64	0.59	0.50	1.30	1.34
0805	OCT 06	1800	30241	2.64	1.00	5.57	1.54	0.52	0.25	4.63	1.10	3.13	0.25	24.49	1.24	3.25	0.25	10.06	0.50	5.33	1.97	5.89	0.50	15.63	2.22
0807	OCT 06	2000	30350	2.27	1.00	6.70	1.70	0.55	0.25	5.13	1.14	2.79	0.25	4.24	1.39	1.67	0.25	11.00	0.90	5.90	1.03	11.06	0.66	1.13	2.20
0809	OCT 06	2200	30732	2.09	1.00	5.74	1.72	0.54	0.25	4.94	1.27	2.42	0.25	2.11	1.40	1.03	0.25	5.10	0.03	4.04	1.90	2.69	0.93	1.30	2.60
0811	OCT 06	2400	36023	1.40	0.50	4.00	1.00	0.50	0.25	3.64	1.00	1.30	0.25	1.13	1.00	0.61	0.25	1.20	0.25	3.34	1.00	2.17	0.25	0.59	0.50
0813	OCT 07	0200	30713	2.00	1.00	5.06	1.27	0.04	0.25	6.06	1.26	5.23	0.25	2.04	1.00	3.01	0.25	17.30	0.96	3.96	1.76	5.45	0.63	0.50	1.40
0815	OCT 07	0400	25140	2.47	0.50	5.94	1.50	0.56	0.25	5.21	1.09	2.40	0.25	2.21	1.00	0.04	0.25	4.73	1.20	3.29	1.57	1.50	0.76	13.94	1.23
0817	OCT 07	0600	24712	1.76	0.50	6.25	1.00	0.52	0.25	5.23	1.00	6.04	0.25	1.71	1.00	0.00	0.25	4.29	0.67	4.01	1.34	1.27	0.54	1.49	1.00
0819	OCT 07	0800	34360	2.57	0.50	5.79	1.06	0.50	0.25	5.44	1.00	3.46	0.25	1.40	0.50	0.50	0.25	2.17	0.25	4.29	1.00	0.70	0.25	1.00	1.00
0821	OCT 07	1000	30050	1.00	0.50	3.27	2.09	0.25	0.25	1.42	1.00	0.56	0.25	1.00	0.50	0.54	0.25	3.20	0.25	1.47	1.20	1.00	0.25	0.50	1.00
0823	OCT 07	1200	40507	1.47	0.50	4.04	1.41	0.50	0.25	4.99	1.00	2.00	0.25	0.26	0.50	1.17	0.25	5.57	0.25	5.53	1.35	2.62	0.25	1.00	1.00
0825	OCT 07	1400	37259	1.23	0.50	6.40	1.91	0.50	0.25	4.44	1.00	3.92	0.25	0.43	1.00	0.61	0.25	4.23	0.25	4.90	1.51	1.71	0.25	1.56	1.30
0827	OCT 07	1600	39160	1.00	0.50	5.32	1.46	0.50	0.25	4.11	1.13	4.10	0.25	7.00	1.11	33.13	0.50	213.53	1.69	5.35	1.61	67.02	0.52	14.16	1.30
0829	OCT 07	1800	39160	1.10	0.50	4.72	1.04	0.59	0.25	4.24	1.00	3.53	0.25	14.00	1.00	6.47	0.50	52.00	1.49	5.26	1.69	9.27	0.91	1.55	1.11
0831	OCT 07	2000	30706	1.00	0.50	4.33	1.14	0.50	0.25	3.01	1.00	0.90	0.50	11.14	3.12	3.05	1.00	17.05	4.60	3.29	1.53	6.94	1.61	1.00	1.45
0833	OCT 07	2200	42714	2.49	0.50	2.90	1.30	0.50	0.25	5.06	1.13	10.07	0.25	11.79	3.01	6.06	1.22	41.41	7.05	4.73	1.95	10.71	1.74	1.00	1.56
0835	OCT 07	2400	30500	1.00	0.50	4.44	1.10	0.50	0.25	5.10	1.00	7.00	0.25	3.62	3.12	1.66	0.00	9.40	6.04	4.11	1.34	3.03	2.00	1.00	1.00
0837	OCT 08	0200	30050	1.00	0.50	4.19	1.00	0.25	0.25	4.73	1.00	3.72	0.25	1.04	1.90	0.60	0.50	2.40	3.50	3.01	2.02	1.50	0.25	1.00	1.30
0839	OCT 08	0400	26021	1.00	0.50	1.54	1.92	0.25	0.25	1.03	1.00	0.50	0.25	0.50	2.21	0.25	0.50	0.50	4.33	1.00	1.33	0.61	1.59	0.50	0.50
0841	OCT 08	0600	26050	1.00	0.50	3.93	1.92	0.50	0.25	6.39	1.00	1.69	0.25	2.31	1.51	0.50	0.50	1.55	2.79	2.94	1.35	2.56	1.12	0.50	0.50
0843	OCT 08	0800	32513	1.00	0.50	5.09	1.37	0.50	0.25	6.71	1.00	2.07	0.25	2.02	1.15	0.56	0.50	2.60	2.02	4.14	1.29	0.82	9.00	0.50	0.50
0845	OCT 08	1000	30907	40.14	0.50	5.13	1.54	0.50	0.25	5.40	1.00	5.33	0.25	3.17	1.00	0.97	0.25	4.90	0.60	5.05	1.10	2.02	0.50	9.59	0.50

VOLATILE ORGANICS (ppb), GALT WPCP
PROJECT 431

FILENAME : GALTVOLA.WK1

12/19/88

SAMPLE DATE TIME I.D.	FLOW (m^3/d)	CHLOROFORM		1,1,1-TRICHLOROETHANE		BENZENE		TRICHLOROETHYLENE		TOLUENE		TETRACHLOROETHYLENE		ETHYL BENZENE		p & m - XYLENE		1,4-DICHLOROBENZENE		O-XYLENE		1,2-DICHLORO BENZENE	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
0847 OCT 88 1200	42005	1.00	0.50	2.73	1.15	0.50	0.25	2.73	0.50	1.59	0.25	2.40	1.00	0.50	0.25	2.30	0.25	3.54	0.50	1.37	0.25	0.50	0.50
Num Data Points	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
Average	36327	3.29	0.97	5.24	2.15	0.77	0.26	4.41	1.01	9.76	0.32	27.71	8.57	7.00	0.45	39.57	1.00	4.22	1.44	9.65	0.54	2.14	0.89
Std. Deviation	10030	5.25	0.51	1.25	0.77	0.35	0.07	1.11	0.41	21.50	0.44	73.80	16.01	27.45	0.61	151.27	1.61	1.20	0.49	29.00	0.60	3.92	0.62
Minimum Value	0	0.50	0.50	1.00	1.00	0.25	0.25	1.00	0.50	0.25	0.25	0.50	0.50	0.25	0.25	0.25	0.25	1.00	0.50	0.25	0.25	0.50	0.50
Maximum Value	50571	40.14	3.00	9.00	4.78	2.04	0.92	8.71	4.60	121.71	4.55	434.27	120.07	210.90	4.91	1146.77	9.50	7.00	4.61	275.73	4.12	22.54	4.61